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DIESEL'S RATIONAL HEAT MOTOR.

BY E. D. MEIER.

All power which man uses, and all forces which he tries to curb and turn to his own purposes, have their origin in heat. Whether we spread the sails of a clipper to a spanking breeze, or urge an ocean greyhound at nearly railroad speed across the Atlantic ferry; whether we propel cars in the streets of Buffalo with electric force generated by the Niagara Cataract, or carry heavy packs on the backs of horses over frozen Klondike trails, we are using in some form the energy poured forth in lavish profusion by the central orb of our system. His heat caused the air currents, which waft the ships to our shores; ages ago his rays called forth primeval forests, whose charred and compressed remains are fired under our steam boilers; vapors raised by his power from the waves of the ocean fall in life-giving

rains on our continent, alike raising the level of the Great Lakes, whose waters feed the mighty cataract; and, in co-operation with his direct heat, call forth bloom and fruit on the fertile fields whence man and brute nature alike derive their sustenance. Man, rising above the animal in his appreciation of the blessing of labor, first applied muscular force, and next what we are wont to designate as the natural forces, to assist him in his restless activity of production. Oars, levers, treadmills and all manner of harness for horse and steer preceded the use of wind or of falling water.

For centuries wind- and water-power were sufficient to drive all his machinery. The expansive force of steam, discovered by the ancient Egyptian, served but for a few simple actions, purposely enveloped in mystery to strengthen the superstition which priest-craft considered necessary for its schemes of government.

Even war, the delight, the pastime and the sole means of support of kings and nobles through many centuries, was slow in finding its most powerful agent in the explosive force of suddenly liberated heat. Finally, it was late in the seventeenth century that attempts were first made to utilize the expansive force of steam or of gunpowder in pumping water and for other useful purposes. And then, after the first experiments had demonstrated the tremendous force contained in these agents, these phenomena for a full century were of interest only to philosophers; and when Watt finally succeeded in harnessing the power of steam and making it work his will, inventors were already busy with engines designed to produce motive power by the explosion of gas or vapors.

Through all these centuries the forces employed were recognized by their effects, and no one suspected that the primal cause of all was the power of heat. Or, if we see in the early worship of the sun, as the great life-giver, some dim appreciation of this great physical fact, it had never yet risen to the height of faith or knowledge, nor had any one dared to attempt to measure and weigh heat in units of force.

The first heat motor which became a practical success-

the steam engine—was for many years developed simply by gradual improvement of its mechanical appliances without any appreciation of the fact that heat economy was the primal consideration. It was, perhaps, well that this was so. Had the early inventors and designers of steam engines understood the limitations to which the steam engine is subject, they would hardly have attempted to develop a machine which, after 100 years of experiment, and another century of practice by the master minds of each generation returns in work less than one-seventh of the potential energy residing in the fuel with which it is fed. And had they turned their attention to machines aiming at more direct transmutation of heat into work, the mechanical difficulties which would have confronted them might have retarded the industrial progress of the world by a full century; for, with all its defects as a vehicle of heat energy, steam has at least the one advantage that it can be used at very low pressures. The early engine gave results which, for the time, were of sufficient and even great value with pressures of less than 10 pounds to the square inch. Materials for higher pressures and temperatures were not available. These materials themselves had to be produced in larger variety and of better quality so that gradual increase in the pressure carried should give us as gradual an increase in fuel economy.

If the early inventors of internal-combustion motors were proceeding on more rational lines, so far as the final outcome was concerned, they were kept back, and in many instances their efforts were foiled altogether by physical difficulties which required greater knowledge of metallurgy and greater mechanical skill than the world then possessed. For a full century the steam engine dominated the whole industrial field, and, until twenty years ago, it stood without a rival.

To an American engineer, Benj. Thompson, also known as Count Rumford, the world owes the first attempt to find an equivalent of heat in work, and the discovery that heat is not matter, but a form of energy. This important fact was communicated by Thompson, then residing in Munich, Bavaria, to the British Association for the Advancement of

Science, just 100 years ago. Other experimenters followed, but it was not until much later that Joule, in England, and Mayer, in Germany, determined and fixed the mechanical equivalent of heat. Early in this century, Sadi Carnot, in France, developed the theory of a perfect heat engine, yet it was a long time before the clear reasoning of these men, though enthusiastically received and elaborated by Rankine, Zeuner, our own Thurston and others, found its way into the designing room of engine builders. For a long time the steam engine was studied only in its mechanical aspects, and the striking success of Corliss, while a great stride toward mechanical perfection, tended rather to retard than to accelerate the study of the steam engine as a heat engine. It is still within the memory of most practicing engineers of to-day, that Hirn, by his wonderful series of experiments at Mulhouse, and his beautiful analysis of the results, aroused mechanical engineers to the importance of considering the utilization and conservation of heat in the steam engine, as the fundamental question of design.

Naturally enough then, when steam was once recognized, not as the cause, but merely as the vehicle of the energy to be transformed into mechanical work, interest was revived in other heat motors. The experimental work of the beginning of the century was looked up, and the means and methods of the earlier inventors of engines, employing gas or oil vapors, were examined by many scientific and skillful engineers, who believed that there must be a more direct way of converting heat into work, than the one through furnaces, boilers, and a long line of steam piping to the cylinder where the conversion takes place.

Isherwood's conclusive experiments in regard to the waste resulting from the physical properties of steam, had their due influence. Higher temperatures were sought, resulting in higher pressures, reheating, and in increasing the number of cylinders. From the 4 to 8 pounds pressure of the earlier days, which could be contained in wooden boilers, such as some of you may remember to have seen in the Water Works in the city of Philadelphia, we have advanced to the 200 pounds and more, carried by the great

marine boilers of our ocean greyhounds and cruisers, and engineering schools possess experimental engines intended to determine the practicability of going up to 300 and even 500 pounds to the square inch. The vast industrial development brought about by the steam engine has given us metals, methods and data, which enable us to contemplate such pressures with equanimity, and have developed lubricants capable of withstanding temperatures which ten years ago were prohibitory.

A little more than a year ago, Professor Thurston published a scholarly discussion of the "Promise and Potency of High-Pressure Steam." His data were compiled from a number of careful tests on the triple and quadruple expansion engines of Sibley College, engines specially designed and admirably handled with a view to determining the possibilities and limits of progress in that direction. He concluded as follows:

"With equally excellent design, construction and management, we may expect the efficiency of the steam engine, with increasing pressures, to increase nearly as the logarithm of the boiler pressure.

"Gain in economy, by increasing pressures simply, must be expected to be slow and to steadily decrease in rate of gain as pressures rise, making the practicable, commercial limit a pressure comparatively low.

"The direction in which to seek for gain are the reduction of internal wastes and the production of a superheated steam engine."

According to this, if we can count in practice on 12 per cent. absolute efficiency with steam at 200 pounds, 14·2 per cent. would be the outside limit at 500 pounds, and 15·6 per cent. at 1,000 pounds steam pressures.

And in this reasoning the increasing difficulties of steam production and boiler economy at the higher pressures have not been considered. As he elsewhere finds cylinder condensation to account for from 18 to 34 per cent. of the total steam expended, the use of some more reliable vehicle for the heat than steam becomes imperative. Thurston's critical examination of the future prospects of the steam engine

then points the way to the production and direct application of the heat at the very point where its energy is to be translated into work.

Thus, after an exhaustive analysis of experiments made with special steam engines of a higher and more developed type than are as yet to be found in practice, he arrives at definite conclusions which confirm and fix in exact limits the prophecies of men like Zeuner, Rankine and a host of others who have given eloquent testimony to the fact that the steam engine is wrong in principle. Thirty years ago Redtenbacher wrote to Zeuner that "the principle of steam generation and utilization is wrong; it is to be hoped that at a time not far distant, the steam engine will disappear after we have acquired clear ideas on the nature and effects of heat."

All these utterances of men of genius naturally led to a renewal of interest in the internal combustion engine. Ericsson's brilliant failure in his attempt to substitute air for steam, and the final relegation of the hot-air engine to very small domestic pumping plants, seemed to put air out of the question as the vehicle for the heat.

The internal-combustion engine, experimentally developed by Barnett, in England; Drake, in America, and Lenoir, in France; improved by Brayton, Barsanti and others, and ably discussed and advocated by Dr. Siemens, became a practical motor in the hands of Otto in 1876. Otto's master patent, at first attacked as being but an adaptation of Beau de Rochas' theories, was sustained in the leading patent offices of the world, and became the foundation on which men like Priestman, Crossley, Atkinson, Capitaine, Clerk and others too numerous to mention, developed infinite varieties of type with a gradual and satisfactory increase in economy.

But they all worked in more or less beaten paths. The value of compression of the charge before explosion was recognized as increasing the initial pressure in the working cylinder. Means and methods for producing retarded combustion (the Nachbrennen of the Germans), or of slowing down the explosive action, were proposed and criti-

cised with equal acumen and quite an expenditure of thermal units on the part of the disputants. Some of the mechanical devices evolved, reflect the greatest credit on the skill and persistence of their inventors. But no one attempted a vital change in the cycle itself until Diesel appeared in the lists. Untrammeled by any previous experience in gas- or oil-engine construction, he was intent only on giving the clear and beautiful ideal of Carnot practical and tangible form in a working engine. He experimented with various vapors more permanent than steam, until the very mishaps and difficulties encountered brought him face to face with the fact that the atmosphere about us could furnish a cheap, endless supply of a permanent gas, available not only as the vehicle of the heat, but as the means of evolving it from the fuel employed.

Rudolf Diesel is a Bavarian, forty years old. He received his early education in Paris, where his parents then resided, until they were forced to emigrate, in 1870, by the decree of the moribund Empire. He is a man of strictly temperate habits, a good mathematician and thoroughly versed in the science of thermo-dynamics, which he has made his life study. As a student at Munich, he was a pupil of the celebrated Professor Linde, now well known as the inventor and builder of the excellent ice machine which bears his name. Since the publication of his lecture of June 16, 1897, he has been fairly overwhelmed with praise and congratulations by the leading professionals of Europe. Perhaps no better gauge of the strong common sense and real greatness of the man can be found than the fact that all this praise and adulation has not turned his head in the least. He remains the same simple, earnest, conscientious student that he was before his great invention dazzled the experts in his line of engineering.

I was particularly struck with the simplicity, and I might almost say humility, with which he spoke of his great achievements. He considers his present success only as an incentive and a stepping-stone to further work and progress. He is very accurate in all his statements, and

thoroughly honest. Nothing can induce him to confound even his most sanguine hopes with a promise of any future success. He patiently and good-humoredly answered all my questions, and was instantly ready to show me authorities for his statements from the carefully chosen books of his extensive library.

As an engineer, he is more theoretical than practical, but has now at his command some of the best practical talent of Germany. Professionally well equipped and clear in his ideas, he is so simple and amiable in his manner that it is a pleasure to work with him, and these characteristics of the man promise to make the working together of the various interests in the many countries in which he has issued licenses satisfactory and beneficial to all, and will make a rapid progress in the practical development of the invention possible.

Mr. Diesel has been at work on the theories on which this motor works ever since he was a student at the Munich Polytechnic School. For the past fifteen years he has devoted himself almost entirely to this work. He even built a small experimental motor in Paris many years ago, the working of which enabled him to modify his first theories considerably. He, however, took the precaution to have the parts of this motor constructed in different shops to prevent his ideas and processes from becoming known. In 1892 he made his applications for his first patent in different countries.

In 1893, then residing in Berlin, he published a book on a new motor, which was translated in 1894 into English by Mr. Bryan Donkin, M. Inst. C.E., under the title "Theory and Construction of a Rational Heat Motor." In this little book Mr. Diesel developed an entirely new idea. It was this: To begin the work of combustion by first compressing atmospheric air to a point where its heat would become sufficient for ignition, and then gradually forcing into this compressed air a small quantity of pulverized fuel. This whole work was to be done in the cylinder of the motor, so that no heat would be brought into it from without. Mr. Diesel not only developed the theory, but suggested the

leading principles of construction. At the time this book hardly went further than into the libraries and studies of men specially interested in the theory of thermodynamics. But Mr. Buz, of Augsburg, the general manager of the great machine works there, placed means and men at the disposal of Mr. Diesel, to enable him to work out his theory in practice, and a 12 horse-power motor was built there, on which many experiments were made. The improvements suggested were embodied in a second machine of the same size, and from this was evolved the 20 horse-power motor which established the working type now adopted. Mr. Fr. Krupp, of Essen, the German Steel King, also became interested in the matter. Mr. Diesel moved to Munich so as to be able to give his whole time to this work.

In the meantime, in 1895, a Mr. Schmidt, of Cassel, worked out and exhibited a steam engine working with highly superheated steam. For the time this motor attracted the attention of the engineering world; its defects were, however, so apparent that it did not come into general use, but it did serve to withdraw attention from Diesel and his work. On the 16th of June, 1897, Mr. Diesel delivered a lecture before the National Society of German Engineers at Cassel, in which he not only developed his theories, but exhibited in drawings the actual construction of his motor, and gave some data in regard to practical results obtained at Augsburg. Prof. M. Schroeter followed Diesel in further development of the theory of the motor, and gave in detail the results of tests made by him on the first experimental motor, and stated his conviction that the motor was now ready for commercial work. (These essays were published in the *Zeitschrift des Vereins Deutscher Ingenieure* of July 10th, 17th and 24th, 1897.)

At the conclusion of these papers a wave of enthusiasm swept over the large audience of professional engineers, and the desire naturally arose to see the motor at work. Mr. Diesel extended invitations to all engineers and manufacturers to visit the works at Augsburg and examine and test the motor for themselves. This invitation has been so generally accepted that for the next nine months the motor

was practically on exhibit for every hour of the day, under the closest inspection by engineers, not only from Germany, but from every civilized country. It was therefore necessary to keep it running as a petroleum motor, and not until a month ago was it possible to dismantle the engine in order to make the slight but important changes necessary to adapt it to experimental work on gas.

Mr. Diesel's idea was to follow Carnot's cycle strictly, obtaining the lower isothermal and adiabatic curves by compression and the upper ones by combustion and expansion. For a long time he experimented with various vapors, which, under normal conditions, are far above their point of condensation.

Ammonia vapors, especially, seem to have the properties best suited to the theoretical process. But great difficulties in handling them were encountered in practice. In the endeavor to replace them he was naturally led to experiment with air. Up to this time he had necessarily applied his heat from without and was subjected to the losses and limitations due to the metal walls through which it had to pass. He was then subject to the same losses which had defeated Ericsson, and was compelled to make the step which made his motor an internal-combustion engine. Starting out, then, with the intention of improving the caloric process of the steam engine, he reached, in a round-about way, means similar to those employed in gas and oil engines. But this similarity is strictly limited to the *fact* of internal combustion, the *method* of combustion being radically different. Further, finding that to begin his compression isothermally, led him into pressures which must, in our present practice, be considered excessive, he abandoned that part of the Carnot cycle and made his compression adiabatic throughout, thus reducing the necessary pressures from over 100 atmospheres to between 30 and 40. When, as in the history of the steam engine, these higher pressures become practically feasible, a return to the original complete process may become advisable. Mr. Diesel's fundamental invention is then really a process for converting heat into work; this, of course, has been supplemented by other in-

ventions naturally growing out of the persistent and logical development of a practical machine to operate on this process. I am happy to have available the description and opinion of no less an authority than Lord Kelvin, written by him after a careful investigation of Diesel's claims, and I will quote it in full.

"The invention may be defined as follows: (*a*) — (*h*).

"(*a*) Use a quantity of air very large in comparison with the quantity of fuel and which may be much larger than is required for complete combustion of the fuel. This air, at the beginning of (*b*) is at atmospheric temperature *T*; and is at a pressure somewhat above atmospheric pressure in virtue of the operation (*h*) described below, unless this operation is omitted.

"(*b*) Compress this air adiabatically to a temperature far above that required to ignite the fuel under pressure.

"(*c*) Immediately after the dense air thus heated has commenced to expand, inject into it the fuel, whether gaseous or liquid, or finely powdered solid, thus causing the fuel to burn as it enters and to prevent, by the heat so generated, the expanding air from going down in temperature.

"(*d*) Regulate and distribute through a prescribed portion of the working stroke of the working piston, the admission (*c*) of the fuel.

"(*e*) Use a governor to alter the duration and amount of the combustion (*c*) according to varying requirements of varying circumstances.

"(*f*) After the introduction of the fuel ceases, continue the expansion until the air is cooled sufficiently, nearly down to the atmospheric temperature (without any abstraction of heat by a water jacket). It becomes cooled to exactly the atmospheric temperature when it sinks to the atmospheric pressure, provided the concluding operation (*h*) of the cycle is properly adjusted, according to the extent of the operations (*b*) (*c*) (*d*) (*f*).

"(*g*) Reject the whole or part of this air from the machine, and take in fresh atmospheric air instead, to make up the whole quantity with which we commenced in (*a*).

"(*h*) Keep, now, this air at atmospheric temperature by

injected water, and compress it to such a pressure as shall cause the fulfillment of the condition stated at the end of paragraph (*f*). This operation may be advantageously omitted, with some sacrifice of theoretical thermodynamic economy, but probably with practical advantage, in smaller types of engine.

"If regulation (*d*) of operation (*c*) were so conducted as to keep the temperature at an absolutely constant degree (*S*) during the portion of the working stroke to which it refers the series of five operations (*b*) (*c*) (*f*) (*g*) (*h*), would constitute an absolutely perfect Carnot cycle for the production of mechanical effect from a quantity of heat given at the temperature *S*, with *T* as the lowest temperature available for carrying off waste heat. The conditions, of course, cannot be *perfectly* realized in any real machine; but Diesel has shown how to make a good, practical approximation to their fulfillment, whether the fuel be gas, powdered solid or oil. He has already, with oil as fuel, realized this approximation with exceedingly good practical results, and has actually obtained 58 per cent. more work than any that has been given, from the same weight of oil, by any of the best oil motors previously made.

"The best economy of oil motors recorded in *The Gas and Oil Engine*, by Clerk (Longmans & Co., 1896), is 371 grams of oil per B.H.P. hour, and the Augsburg tests of the Diesel engine give 234 grams of oil per B.H.P. hour.

"Besides this great advance in economy of fuel, Diesel's invention has given many collateral advantages of much practical importance. By supplying the fuel gradually to hot expanding air during a determined part of the working stroke of the main piston, and, by using a much larger quantity of air than that required for complete combustion, he keeps the highest temperature reached by his engine several hundred degrees centigrade lower than the temperature essentially reached in the working cylinders of previous gas and oil engines. And the expansion after the end of the combustion gives a much lower temperature of exhaust without cooling by water jacket, than both expansion and water jacket together give in other gas and oil engines.

"Diesel's process of heating the air, simply by compression, to a temperature far above the igniting point of the fuel, before the fuel is introduced to it, supersedes all use of flame or hot chamber for ignition, even when the engine, cold in every part, is started for its first stroke by energy stored in a compressed air vessel from its previous working. This capability for instant starting from cold, and for stopping and starting again with perfect readiness at any time, is, I believe, a very valuable item of superiority, for many practical purposes, over any gas or oil or other interior-combustion engine, previously made. Diesel's invention of introducing the fuel into air previously heated to far above the igniting point, merely by compression, and so causing the fuel to ignite, is, in my opinion, thoroughly original, and it has not been anticipated by any previous inventor. In nearly all previous gas and oil engines, the air and fuel are compressed after being mixed together, with the great disadvantage that the degree of compression cannot go beyond comparatively narrow limits without causing explosion before the compression has ceased. In Barnett's third engine, the air and gas are compressed in separate pumps which, after the compression, discharge their contents into the motor cylinder. There they are ignited by means of a flame controlled by an igniting valve invented by Barnett (being almost identical in principle with the igniting arrangements used by many subsequent inventors). But neither Barnett nor any subsequent inventor anticipated Diesel, in causing the fuel to be ignited by the high temperature produced by previous compression of the air into which it is introduced.

"Diesel is also quite original, and is, I believe, not anticipated by any previous inventor in gradually introducing the fuel into expanding air, and so regulating and controlling the temperature produced by the combustion."

I have just received a paper from a noted Austrian engineer, Mr. Emil Krauss, written after a careful personal investigation of the Diesel motor at Augsburg. Mr. Krauss is known beyond the limits of his own country as an expert on boiler construction and boiler management, and

his official position is such as to qualify and bias him rather as a champion of the steam engine than otherwise. Thus, when I quote his conclusions, I am giving you the conviction of a man whose interest is, if anything, inimical to Mr. Diesel, but whose professional integrity compels him to acknowledge excellence where he finds it.

"I saw such a motor at work in the Augsburg Machine Works last fall, and must state that it impressed me as a completely designed and finished machine.

"(1) The working process, such that heat is supplied only at high temperatures, fills the requirements of a rational heat motor better than any previous heat engine.

"(2) The temperature at which the addition of heat begins is entirely independent of the process of combustion, and is so high that the efficiency, even when a minimum of heat is supplied, cannot fall below that fixed by this initial temperature.

"(3) The influence of the temperature of combustion on the thermal efficiency is so small, that within certain limits this efficiency actually increases with the excess of air in which combustion is effected.

"(4) The regulation of the motor can be consequently accomplished without affecting its economy.

"The first petroleum engine embodying these principles has placed the Diesel motor at the head of all petroleum motors up to date. The same success is probable for the Diesel gas engine; work on this is progressing, and everything indicates that a new success for Diesel will shortly be recorded."

It was Diesel's first intention to build a motor with three cylinders embodying compound compression and compound expansion, and one of this type has been built at Augsburg, and is to be thoroughly tested on producer gas. But the development of the single-cylinder type has been so satisfactory, and the demand for them has become so great, that at present the German shops are busy to their fullest extent building this simpler form. As this form has reached an absolute efficiency of 30 per cent., and is in every way a simple and practical machine, there is at present no reason

for developing the compound motor. The cut here given (*Fig. 1*) represents the first of these 20 horse-power motors, built by the Nürnberg Machine Works. It is at present on exhibit at the Electrical Exposition in New York City. In appearance it resembles a vertical marine engine,

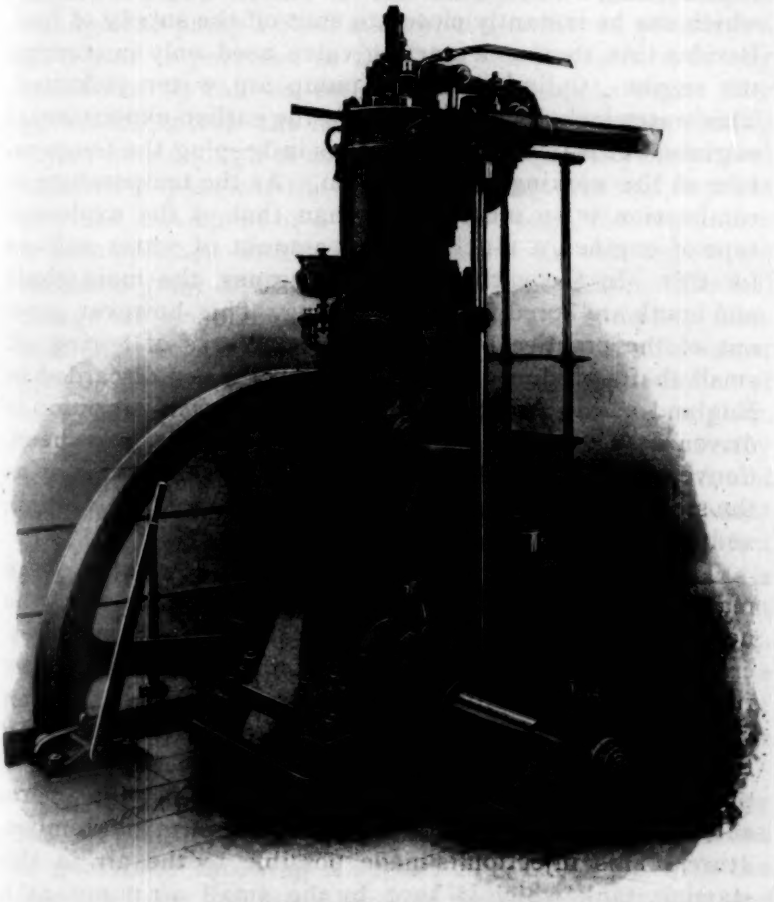

FIG. 1.—Diesel Motor—Perspective View.

a strong base-plate supports the main journals of the crank-shaft, outboard bearings being provided for the shaft extensions which carry the fly-wheel and pulley. Bolted to the base-plate is a stout –A– frame containing the guides. In

the rear leg of this frame, a small air-pump is supported. On top of the frame is placed a cylinder open at bottom. Its top is closed by a head cast in one piece, in which are contained one suction valve for air, one discharge valve for spent gases, and a needle valve for the fuel. The admission to the casing of this fuel valve is controlled by a stop valve which can be instantly closed to shut off the supply of fuel. Besides this, there is a starting valve used only in starting the engine. Cylinder and air-pump are water jacketted. This water jacket was not used in the earlier experimental engines, but is found advantageous in keeping the temperature of the working parts uniform. As the temperature of combustion is so much lower than that of the explosion type of engines, a much smaller amount of water suffices for this. In the earlier German engines, the main shaft and crank are bored for water cooling. This, however, grew out of the practice of Krupp's Steel Works of boring all small shafts produced. The practice has been discarded in England and in America as unnecessary. The air-pump is driven by a set of levers attached to the main cross-head. Conveniently placed to one side is an air vessel, known as the starting tank, connected by copper pipe to the air-pump, and to the fuel valve casing.

The operation is as follows: On one down-stroke the main cylinder is completely filled with pure air, the next up-stroke compresses this to about 35 atmospheres, creating a temperature more than sufficient to ignite the fuel. At the beginning of the next down-stroke, the fuel valve opens, and the petroleum, atomized by passing through a spool of fine wire netting, is injected during a predetermined part of the stroke into this red-hot air, resulting in combustion controlled as to pressure and temperature. This injection is made possible by the air in the starting tank, which is kept by the small air-pump at a pressure some 5 to 10 atmospheres greater than that in the main cylinder. A small quantity of this air enters with the fuel charge, which it atomizes as described. When the motor is running at full load, a very small quantity of injected air suffices, and the pressure in the air tank steadily

rises. At half load, with less fuel injected, more air passes in. For this reason, the starting tank is made large enough to equalize these differences, and a small safety valve is provided on the air-pump.

The petroleum is pumped into the fuel valve casing by a small oil-pump bolted to the base-plate. This pump is arranged to pump a fixed maximum quantity of petroleum. A by-pass is provided so that this whole quantity, or any portion of it, can be returned to the supply tank. The governor controls the action of this by-pass valve, closing it just long enough to compel the exact quantity of the fuel required to pass into the fuel valve casing. As this requires only the movement of a small light wedge, the regulation is accomplished with great exactness. In this regulation resides a great advantage for the Diesel motor. The full charge of air being always supplied for complete combustion, it matters not whether the governor permits one or fifty drops of petroleum to enter the working cylinder at each motor stroke, the combustion is always complete. Thus variations in excess of air over that theoretically necessary, from 26 to 116 per cent. have been measured, and the analysis of the spent gases shows no trace of unburnt carbon or hydrogen. It is hard to conceive a more perfect combustion than that which takes place when fuel is sprayed, finely powdered or atomized into red-hot air, just beginning to expand. To stop the motor it is only necessary to close the valve which admits the petroleum into the fuel valve casing. The valve gear consists of a series of cams placed on a shaft journalled on brackets cast on the cylinder.

In starting the motor a hand-lever is pulled to one side throwing all these cams, except the exhaust valve cam, out of gear, and throwing a special cam into gear with the starting valve. A few strokes of the petroleum pump by a hand-lever inject a small quantity of petroleum into the fuel valve casing. The fly-wheel is thrown over by a lever a trifle beyond the upper dead point. The fuel throttle valve is opened, and, by a turn of the hand-wheel, communication is established between the air tank and the start-

ing valve. A single charge of highly compressed cold air enters the cylinder, sufficient to give two revolutions of the fly-wheel at moderate speed. At the close of the first revolution, the starting valve cam is automatically thrown out and the other cams into gear, thus on the second revolution, a full charge of air is drawn in and compressed, and in less than thirty seconds the motor is running at full speed.

It will be noted from Lord Kelvin's clear analysis of the working process of the Diesel engine, that Mr. Diesel makes a sharp distinction between the temperature of ignition and the temperature of combustion; the first is a constant value at each pressure and dependent only on the physical qualities of the fuel, the higher the pressure the lower the temperature of ignition. The temperature of combustion on the other hand is variable, depends on many conditions, and especially on the quality of the air by which the combustion is maintained, but it is always higher than the temperature of ignition.

Diesel's radical departure from all previous practice is in generating a combustion temperature by mechanical compression of pure air, utilizing this temperature to ignite the fuel, and by so introducing the fuel that the heat lost by expansion is practically balanced by the heat added by combustion.

Before the completion of this perfect engine, certain critics of Diesel's theories contended that the dimensions of the cylinder and all other working parts would become so great as to make it impracticable to build such engines. But in Diesel's engines, the increase and the decrease in pressures are so gradual, that there is no shock. The change from one to the other is always accomplished at a dead point. In all motors relying on explosion for their moving force, and even in the steam engine there is a direct blow at the moment of ignition or admission. I present here a drawing on which indicator diagrams of a high-pressure steam engine, of an explosion-type oil motor and of a Diesel motor, have been drawn based on the same piston displacement (*Fig. 2*).

Diesel's and the explosion-motor diagrams can be directly compared since both work on the four-stroke cycle. The steam-engine diagram should be quadrupled. This disposes of the objections just referred to.

These second and third diagrams (*Figs. 3* and *4*) are graphic comparisons of the Diesel motor with a number of

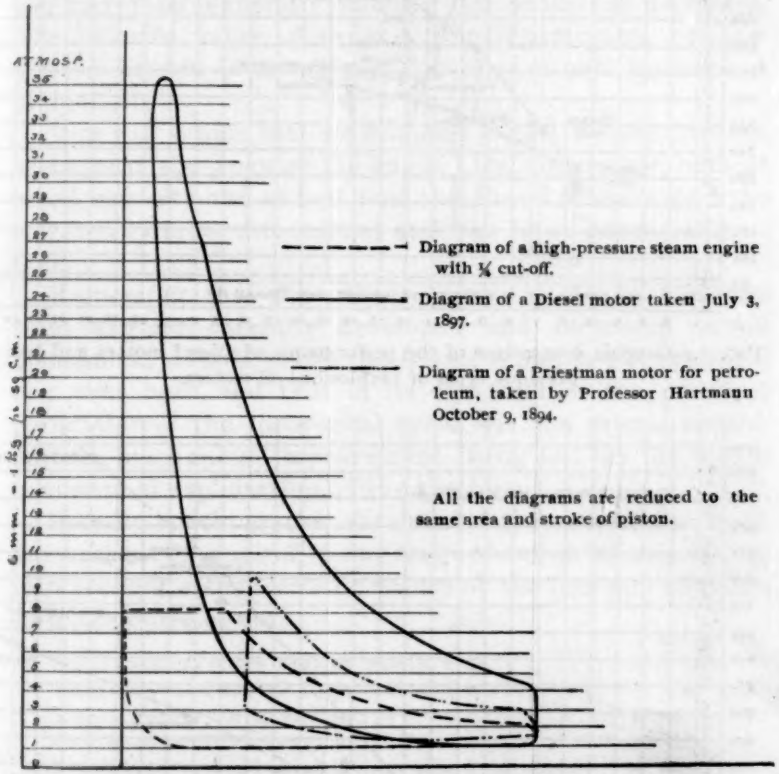
ATMOSP.
Diagram of a high-pressure steam engine with ¼ cut-off.
Diagram of a Diesel motor taken July 3, 1897.
Diagram of a Priestman motor for petroleum, taken by Professor Hartmann October 9, 1894.
All the diagrams are reduced to the same area and stroke of piston.

FIG. 2.—Comparison of diagram of a Diesel motor with diagram of a steam engine and of an explosion-motor.

the best petroleum motors as to economy in fuel and volume swept by the piston per second. They are given on the authority of Professor Hartmann, well-known as a careful and conscientious observer in this field.

The abscissæ represent piston displacement in liters per second, the ordinates petroleum consumption in grams per

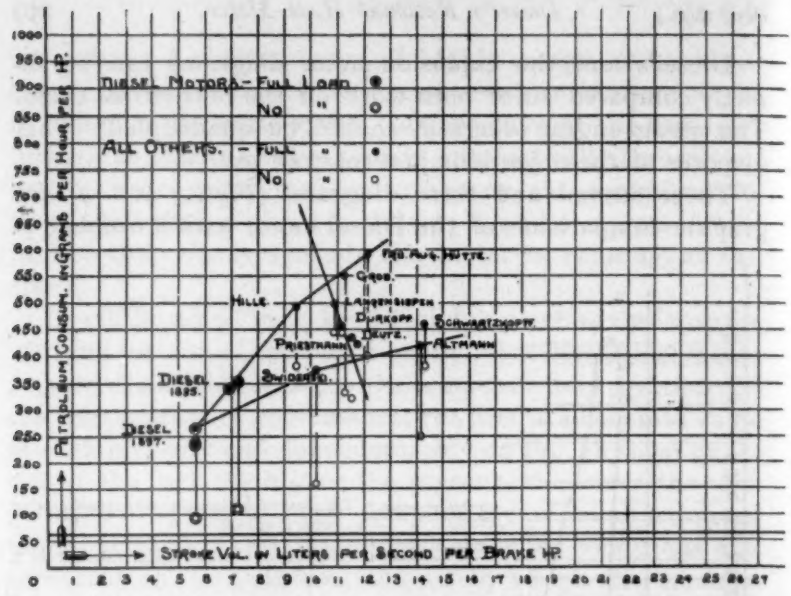

FIG. 3.—Graphic comparison of the performance of Diesel motors and best previous types of (explosion) oil motors.

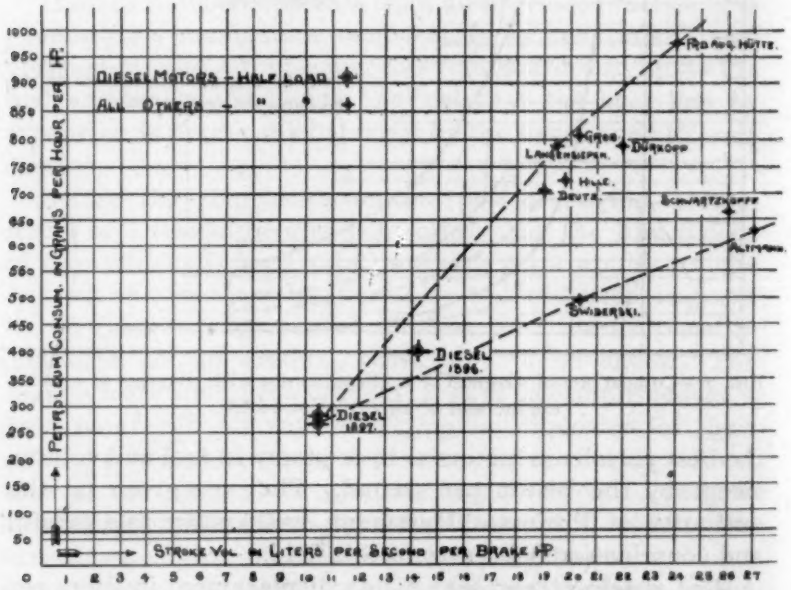

FIG. 4.—Graphic comparison of the performance of Diesel motors and best previous types of (explosion) oil motors.

hour, both figured on the effective or B.H.P. The full lines (*Fig. 3*) embrace the results for full load, the dotted lines (*Fig. 4*) those for half load. The comparison is between engines which burn ordinary safe lamp petroleum or kerosene; results obtained on benzine or naphtha are not considered, since motors depending on such dangerous fuels can never be generally adopted for industrial purposes. The calorific value of these highly inflammable and explosive liquids is no greater than that of safe kerosene or of fuel oil.

You will notice that we find the Diesel results in both cases near the apex of the angle. Or, plainly put, both at rated capacity and at half load the Diesel motor shows the smallest cylinder dimensions and the least expenditure of fuel.

Remember that the others represent the best results from engines carefully developed and improved in all mechanical details, while the Diesel motor is but the third one ever built, and that in its construction the practical realization of the theoretical cycle was the primal consideration, mechanical improvement being left for the future commercial exploitation of the machine.

Broadly speaking, the absolute efficiencies of the best-known heat engines of to-day range about as follows, taking into account actual calorific values of the fuel and effective or brake horse-power:

	Per cent.
Small auxiliary steam engines, pumps, etc.	$\frac{6}{10}$ to 1
Plain slide-valve engines in good condition	3 to 5
Single-cylinder Corliss engines	6
Compound-condensing engines	8
Reheating-compound or triple-expansion steam engines	12
Best oil engines (explosion type)	16
Best gas engines (explosion type)	19
Diesel motor	28 to 30

All these are compared when running steadily at full load or rating at point of best economy.

But in a large majority of the applications of all these prime movers the exigencies of the service require them to be run frequently at three-quarters and at half load for a large part of their daily service.

It is conceded that in most engines the internal frictions or mechanical losses are a fixed amount, so that a loss of 15 per cent. at full load becomes 30 per cent. at half load. And thermal losses increase even more rapidly; for instance, in steam engines by cylinder condensation. In gas and oil engines the absolute efficiencies have in some cases shown a measured loss of nearly 60 per cent. In the Diesel motor the thermal efficiency is shown to increase with decreasing loads, thus counteracting in a marked degree the loss in mechanical efficiency which it shares with the other machines. From a number of carefully-checked tests, I found the average drop in absolute efficiency from full to half load to be only 12 to 13 per cent. in the Diesel motor.

So promptly and easily does it respond to a change of load, that a sudden addition of 30 per cent. to the electrical load on the Diesel motor at the Electrical Exposition at New York, by the throw of a switch, was not noticed by observers of the engine or the lights, though promptly registered by the ammeter.

For variable loads, then, the Diesel motor will show in practice a much greater superiority over all rivals than that apparent from the tabular figures just given.

The Diesel motor has been fully developed as an oil engine. At first it was tested only on ordinary lamp petroleum, such as is used in every household. But in November last I sent a barrel of American gas oil and four barrels of American fuel oil to Augsburg and Nürnberg, to make conclusive tests in regard to its reliability and economy on these cheap fuels. A series of tests was made, which gave the gratifying results that the economy was the same as on refined petroleum, and the combustion so complete that no fouling of cylinder, valves or exhaust-pipe occurred.

Encouraged by this, the German factories made tests with a cheap fuel oil, distilled from bituminous shale, and called "Solar Oil" in Germany. The result was so satisfactory that motors have since been sold guaranteed to run on these cheap oils, and they are doing this with perfect satisfaction.

American fuel oil is sold, delivered on track in tank cars

and tank wagons, at prices ranging from 1·6 cents to 2 cents per gallon in the West, and from 2½ cents to 3 cents in the East; based on these prices, and allowing the high average of 240 grams per B.H.P. hour, a 100 horse-power Diesel motor will consume about 15 cents' worth of fuel per hour. With coal at $2.80 per ton, the fuel cost per hour for 100 B.H.P. in a good steam engine will be about 54½ cents for a slide valve, 43½ cents for a Corliss, and 22·4 cents for a triple-expansion engine, and to this should be added a fair proportion of the fireman's wages, and for coal-passing and ash-hoisting, none of which charges would be incurred where the Diesel motor is used. Weighing all these facts, it becomes easy to understand the wonderful and unprecedented progress made by Diesel's invention in Europe.

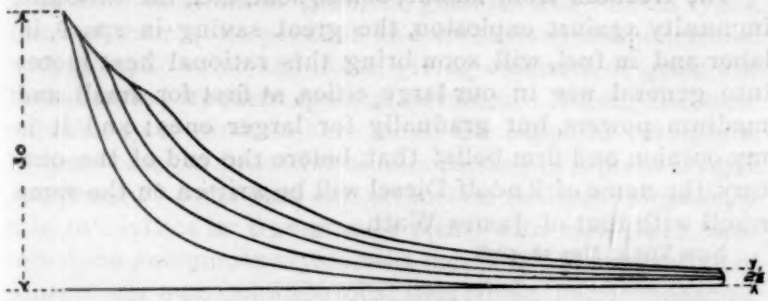

FIG. 5.—Diesel motor used with gas-indicator diagrams when regulating ¼ millimeter = 1 kilogram = 14·7 pounds.

Up to date he has licensed sixteen large machine shops to build his motor, and a conservative estimate of the amount of capital now specially devoted to this work in Europe places it at between four and five million dollars. The invention comes to our shores, not, as so many do, in its experimental stage, but in a complete form, so far as stationary motors are concerned. Designs for railway, street-car and marine motors have been made in Germany and England, and they will probably have passed through *their* experimental stage by the beginning of next year. The adaptation of the stationary motor to gas is practically completed, and a progressive series of tests on various kinds of gas will be run in Augsburg during the summer.

I take pleasure in presenting an enlarged view of an indicator diagram (*Fig. 5*) taken from the motor while running on Augsburg city gas, merely to show you that the same beautiful and economical cycle is possible with gas as with petroleum.

The work of experimenting, developing and testing has been performed with proverbial German thoroughness. American methods of manufacture with special tools, gauges and templates arranged to turn out a large number of duplicates of each size, will soon bring the motor into general use in the United States. To do this, the same broad policy of dividing the work among a limited number of first-class and well-equipped manufacturers, which works so well in Europe, will be adopted here.

The freedom from smoke, ashes, soot, etc., the absolute immunity against explosion, the great saving in space, in labor and in fuel, will soon bring this rational heat motor into general use in our large cities, at first for small and medium powers, but gradually for larger ones; and it is my opinion and firm belief that, before the end of the century, the name of Rudolf Diesel will be written on the same scroll with that of James Watt.

NEW YORK, May 18, 1898.

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A TRIP TO RUSSIA AND THE URAL MOUNTAINS.*

BY GEORGE F. KUNZ.

[*Concluded from p. 214.*]

But, in addition to their metallic wealth, the Ural Mountains have for nearly two centuries been noted for their remarkable productions of gem-like minerals and gems that, for beauty and quantity, have given this region a foremost place in the mineralogical collections of the world.

In particular, the magnificent emeralds, alexandrites, phenacites, gigantic beryls, topazes, tourmalines, green garnets, amethysts, and the great variety of jaspers of all colors, are among those of the greatest interest.

*A lecture delivered before the Franklin Institute, April 20, 1898.

Catherine I, wife of Peter the Great, who named Ekaterinburg in her honor, first paid attention to the development of the precious-stone industry in the Urals; and two of the amethyst mines near Mursinka are to this day called Taljan, a corruption of Italian, she having sent two Italian lapidaries to this region for the purpose of developing the gem resources, founding the lapidary works and establishing an industry which gives employment to at least 1,000 people in this remote region at the present time.

The chief gem districts of the Urals are all within one hundred miles of Ekaterinburg, some eight or ten miles apart. In this limited territory there are over 100 mines or localities where minerals and gem stones of more or less value and great variety are extracted. The rocks comprise a number of kinds of granites, gneisses and related types, some of them quite peculiar, and are seamed and penetrated with granitic veins and dikes, giving evidence of great disturbance and frequent igneous intrusion. Among the more valuable gem minerals here found are sapphire corundum, in some cases of beautiful blue, occurring in a peculiar rock composed of corundum and orthoclase feldspar; topaz crystals, in cavities in true granite veins, with rich green amazon-stone and quartz crystals—a combination suggestive of some of our own Colorado localities; zircon, beryl, phenacite, and a host of other interesting minerals less familiar but sometimes very beautiful as specimens or ornamental stones, or valuable for economic uses in the arts.

The occurrence of the diamond in the Urals has for a long time been questioned. In a collection at Nijni Tagilsk I saw a small white crystal weighing $\frac{1}{8}$ of a carat, a twinned hexoctahedron, which was pronounced phenacite by a local mineralogist, who had taken its specific gravity; but which is, as the writer identified, a small opalescent white diamond, similar to those found at the Bagogem mine in Brazil. It was found in a small brook, near the village of Kalstchi. The existence of pyrope garnets here, and their frequent finding, seems to sustain the theory of their origin, although some of the Russians are quite sure that the Russian who found the diamonds for Humboldt had really deceived him.

The admirable volume on the "Genesis of the Diamond," by the late H. Carvill Lewis, edited by Prof. J. T. Bonney, and the review of the same in *Science*, by the author, G. F. Kunz, fully discuss this subject, and in the Report of the United States Geological Survey, 1896.

At Kornilowog, and near the village of Chitanka, in the washing for gold, transparent corundum is found in the form of sapphires of pale blue color, also yellow, and rubies, light red, sometimes streaked with blue, resembling the Ceylonese rather than the Burmese, and green sapphires associated with fine ruby-red pyrope garnets, blue chalcedony, transparent zircon, quartz, etc. A ruby or sapphire worth $100 is of exceedingly rare occurrence, although many are found that sell for from 1 to 20 roubles each.

The emeralds, alexandrites and phenacites of the Urals are all from one small region, on the right bank of the Bolchoi Reft, a little north of Takowaja, fifty-one miles northeast of Ekaterinburg and quite apart from the other localities in Perm.

The emerald mines consist of four large groups of mines and a number of smaller workings; starting a little north of Takowaja, running north and west a distance of some seventeen wersts, or ten miles.

The Troitzk mine is about the central one of the group; the excavations are 1,000 feet in length and 200 feet in width, with shaft holes, wheels, etc., as the evidences of deep, extensive workings. These mines were operated by Pavlevsky, and also under the crown.

The Lubinsky mine, also a crown working, is two wersts north of Takowaja; the rock here is principally mica schist interspersed with actinolite and talcose schist. At the Krasnobolskaia, ten wersts south of Troitzk mine, the old shafts, drifts and workings indicate a vast amount of labor formerly carried on. This is the locality that has furnished the alexandrites and phenacites, as well as emeralds.

The Marienski emerald mines, seven wersts (five miles) north of Troitzk, are marked by several workings over 200 feet in diameter.

Among the associated minerals I observed quartz, feldspar, mica schist and chlorophane.

This is the chlorophane mentioned by Pallas, so highly phosphorescent and sensitive that it emitted light by the heat of the hand.

These mines were systematically operated fifty or sixty years ago, at an annual rental to the Government of 60,000 roubles ($45,000)—a charge which finally led to their abandonment, because the mining did not pay at so high a rental. Fine roads were laid to the great Siberian Street, twenty-one miles distant, and mining was conducted on an immense scale; for a distance of some ten miles along the course of the emerald veins, in a line running northeast and southwest, shafts were sunk and tunnels were driven in the talcose schist and mica slate in which were found the fine gems. Strange to say, although now these mines have not been worked for over forty years, and are carefully guarded by the imperial woodkeepers, we see from them to this day single gems for sale in Ekaterinburg, some of them valued at $300 each. It is hard to believe that these are from the original workings of the mine. Possibly they are sold by peasants, who have found them in re-working the old dumps, or who secretly work the mines when they are not watched.

Here also was first found the mineral phenacite, which received its name from *phenos*, meaning deceiver, and *lithos*, a stone, because it was long mistaken for white topaz. It is one of the most brilliant white gems known, but lacks the play of color possessed by the diamond. It was formerly found in connection with alexandrite, a chrome-green variety of chrysoberyl, which exhibits the property of changing from a green by daylight to a columbine or raspberry-red by artificial light. It was named alexandrite in honor of the Czar, Alexander II, by Nordenskiold, in 1842, who discovered it in the then famous emerald mines at Takowaja.

The alexandrites when cut as gems weigh from $\frac{1}{8}$ of a carat up to (very rarely) 5 carats each, though crystals and groups of crystals weighing 20 pounds have been found, so rare is it to obtain perfect pieces even in the large crystals.

About seventy-five localities (see map prepared by P. Kalugin, of Neviansk Savod) in the Government of Perm,

furnish gems or gem minerals. These are at present the property of the Czar, and are worked irregularly by the peasants, when their crops do not require attention.

Little has been done in any of the workings in the way of systematic mining, the method consisting generally in stripping off the rock, or simply following a vein with the use of as little timbering or pillar-building as possible. None of these mines show any great amount of work done; and from what I ascertained on my recent trip, the rights to mine may be offered for sale at a prohibitory figure, as was the case with the emerald mines, resulting in a complete suspension of the search for these minerals, whose finding, working into gems, and sale, furnished a livelihood to fully 1,000 peasants and lapidaries.

Here have been found marvellous crystals of transparent aquamarine, notably the one found on November 19 (December 1), 1828. This is a dark asparagus-green crystal, weighing 6½ pounds, brilliantly transparent, doubly terminated and beautifully marked with etched planes. It was acquired by the museum of the Imperial Mining Institute of St. Petersburg, and was then valued at 43,000 roubles, equalling at the present time $23,000.

At Lewaschinagorka, one mile east of Alabashka, there was found in 1888 a fine yellow crystal of beryl, 5 inches in length and weighing 8 ounces, of a beautiful golden color. Another beryl was found in the mountain of Zolotonah, near the village of Ujakova. This measured 5 inches in length, 2 inches in the widest part and $2\frac{1}{10}$ in its narrowest. It is doubly terminated, with a basal plane at one end, and with pyramidal faces at the other. It is a beautiful sea-green color and showing at the face the pyramid, a slightly fibrous structure is developed.

It weighs 436½ grams, almost 1 pound avoirdupois. Both these beryls are now in the remarkable collection of Russian minerals belonging to Harvard University.

Lewaschinagorka is about a mile east of Alabashka, in the Biserk (district) Alaraensky. A working, irregular in shape, 1,000 feet long and 40 to 50 feet deep, and 50 to 60 feet wide has been made here. It was at this locality

that the writer obtained the large yellow beryl crystal, now in the Garland Collection at Harvard University, was found. The rock here is pegmatite.

Black tourmaline occurs, plentifully interspersed in the orthoclase of all the gem-bearing veins of this district.

Beautiful blue, sea-green and white and sherry-colored topazes, generally transparent, are found at Alabashka and adjoining localities in Perm, some crystals weighing from a few ounces to 4 pounds each, notably a 4-pound one now in Harvard University, in the collection before referred to. There was a great yield in 1880 to 1882, producing many hundreds of crystals absolutely transparent and furnishing gems weighing over an ounce each, at Alabashka, which is situated on a small river of the same name. A number of excavations here have been made varying from 50 to 500 feet in length.

The famous red tourmalines—rubellites—formerly obtained from Chitanka and now from Sarapulka, and one or two other localities, are the most magnificent ever found as crystals, although they rarely afford gems.

At Sarapulka, in the Bizerk of Rejscheski, there are two localities, about 100 feet apart, on the side of a hill, which is one of a number, none of them higher than 100 feet, in a beautiful fertile rolling country. One of these mines was opened over a century ago; the other in 1841. At this place the excavations are now 150 feet wide, and at a depth of 30 feet a shaft is sunk in one of them. Numerous small workings are about it.

Perhaps the most magnificent gems from the Urals are the wonderful royal purple amethysts, changing to red by artificial light, that are found at about forty localities in the Government of Perm. For intensity of color and perfection of quality, and one might say majestic beauty, these rival almost any other colored gem. A series of them was exhibited at the World's Fair at Paris, in 1889, five of which were presented to the Czarina by the peasant who found them. Two of these measured nearly 2 inches across, and are royal purple by day, changing to rich red wine-color by artificial light, as do nearly all the Uralian amethysts.

Besides the purple quartz, or amethyst, other colored varieties of quartz occur, and mention may be made of the smoky shades, which may be altered by heat to rich deep yellow, forming the so-called quartz topazes.

M. Kleiner* says that the miners in the Government of Perm found that crystals of quartz and smoky quartz when taken from the ground and exposed to the air frequently became filled with rents, flaws and turbidity; but that if, immediately upon finding, the crystals were packed in damp sand or other material, and then put in a box and allowed to remain for one or more years in the cellars of their houses —which in the Urals are very warm—their color would not change as it did if exposed at once to the air. This is probably due to the fact that the crystals contain large quantities of liquid carbonic acid, and that at the temperature at which they are taken out, generally in spring or winter, the cavities would explode; whereas, by covering with sand, the same temperature they were found in was preserved.

Kleiner also states that to impart to the smoky quartz a golden yellow color, the peasants would put them in a loaf of bread and then bake them in the oven. When the color was not sufficiently changed, they were baked three or four times. He remarks, however, that the crystals often exploded before they changed color, which fact would substantiate the view that they exploded through the agency of the presence of carbonic acid gas that produced the turbid marking and rents on exposure to the low temperatures.

One of the most beautiful of all gems, and one that was not known two decades ago, is the demantoid (green garnet), or "Uralian emerald," erroneously extensively sold as olivine, found at Poldnewaja, near Syssersk, in the Government of Orenburg.

This form of garnet varies from yellowish-green to a most intense emerald-green, and possesses a high power of refracting light, showing a distinct fire like the diamond or zircon, so much so that in the evening it has almost the appearance of a green diamond. It is found as rounded nodules in a

* Mineralogischer Verein von Russland, St. Petersburg, 1842.

curious serpentine-like rock, and also as loose grains in the gold washings, selling in small gems (the most desired) for almost the price of diamonds of the same size.

The rare mineralogical deep blue gem, euclase, has been found for the past forty years in the gold washings on the River Sanarka, associated with cyanite, for which it was at first mistaken. In 1889 superb sapphire-blue euclases, one a crystal 7½ centimeters long, were found here, one of which was cut into a gem of 4 carats, and sold for over $500.

Passing now from gems and precious stones to the ornamental stones for which Russia is justly celebrated, we note particularly rhodonite, malachite, jasper and lapis lazuli. The malachite of Nijni Tagilsk has been already referred to, and the use of this beautiful material in works of art is a peculiarly marked feature in the palaces and cathedrals of Russia, and in the Russian exhibits in all the great international expositions.

Lapis lazuli is found not so much in the Urals as farther east, in Siberia, in the neighborhood of Lake Baikal. From this far-off region has been brought the material used for veneering the celebrated lapis lazuli columns in the cathedral of St. Isaac's at St. Petersburg, and for many other elegant works of art in the imperial palaces.

Another of the most beautiful ornamental stones—labradorite or opalescent feldspar—is found at a locality in the Government of Kiev, where works for cutting it were founded in 1849 by the proprietor of the estate on which it occurred. This establishment was represented at the World's Fair by a number of articles. The yearly product is estimated at some $26,000, all made by handwork.

Rhodonite (silicate of manganese), in greater quantity and of finer color than anywhere else in the world, is found in the Ural Mountains, in the village of Sedelnikowja, thirteen miles southwest from Ekaterinburg, and at Malazidelinki, some eight miles farther. Its color varies from the richest deep warm pink to a reddish brown. Chemically, it is composed of silica and manganese; and it is almost always associated with pyrolusite and psilomelane, black oxides of manganese, which mark and streak the stone, frequently

adding greatly to its beauty. Its hardness is nearly 6·5, about that of the harder varieties of feldspar and of jade, although not so tough as the latter.

Nearly all the rhodonite of commerce is brought from this Russian locality, where it is found by the ton.

Pieces of fine pink color without the black streaks of oxide of manganese are exceptionally rare, so much so that when the late Empress of Russia, who was very fond of it, ordered, it is said, a piece cut the size and shape of an egg, that was to be free from all blemishes or black streaks, over one ton was cut for this purpose without obtaining enough for the desired piece.

Nowhere else in the world is jasper so abundant, and found in such endless varieties of color; it is obtained principally in the Government of Orenburg. One of the most highly prized colors is a rich gray-green; and also red, mottled with yellow and green, which form an endless series of combinations. It also is found in beautiful colors in the Guberline Mountains, near the city of Werchne Uralsk, 100 miles south of Zlatoust. A superb green jasper is obtained from the River Achtuba and from the River Ohra.

The jasper found in the Kalkansky Mountains, ninety-five miles from the city of Ohrsk, in the Urals, is of a gray to a grayish-green color, with a very fine-grained texture, and is an ideal substance for lapidary work. The most delicate touch of the wheel or graver is perceptible. The stone admits of a high polish, but the texture is so fine that a dull or mat surface is equally beautiful. It may be likened to a rich gray putty, on which the slightest touch of a razor-edge remains as a true impression. The contrasts between the polished and dull surfaces afford opportunity for very beautiful effects. This is one of the most highly prized of Russian ornamental stones.

I was present when a dish of Kalkansky jasper was presented by the city of Tscheliabinsk, in the Government of Orenburg, to the Czarevitch, on the second of August, 1891, at a reception given him at Troitzk (the first city out of the steppes), on his return from the great trip across Siberia.

This dish, which was 18 inches in diameter, represented a fluted platter, entirely covered with grape leaves, most of which were arranged or laid on so as to have the under or pale side up. At the edges, however, the leaves were turned up and over, so that in looking down on the dish the leaves all around the edge showed their bright upper side to a height of 2 inches, thus forming a border. The outer and upper edges, as well as the veinings on all the leaves, were polished, while the lower side of the leaves that was visible was dull. The grayish-green color of the Kalkansky jasper when unpolished exactly simulates the dull tint of a grape leaf. Several men were steadily employed for one whole year on this dish alone.

With this was also a small salt-cellar, similarly made of grape leaves, the stems of the leaves serving for feet, to carry out the ancient custom of presenting royalty with bread and salt on entering a city.

The Russian Czars have taken pains to develop the industries connected with these valuable and beautiful materials, and have founded great establishments for cutting and polishing ornamental stones, at which a kind and amount of work has been produced that is not equalled in the world. Chief among these are the Peterhoff Lapidary Works, at St. Petersburg, the immense establishment at Ekaterinburg, in the Urals, and the lapidary works at Kolivan, in Siberia.

Of these great Government workshops and their products, it is fitting that some account should be given here.

Many small and choice objects, as well as fine mosaic work of hard stone rivalling anything ever produced elsewhere, are made at the Peterhoff Lapidary building, established by Catherine II in 1775; situated between the new and old Peterhoff palaces, about forty minutes' ride from St. Petersburg. It is a three-story building with palatial interior decorations. The central hall is 150 feet square, and the entire building is an example of imperial magnificence. One is surprised to find marble staircases, marble floors, fine high ceilings, and the most elaborate machinery for stone-work. One floor is entirely filled with glass cases

containing stones to be worked up in the building. Here are expended annually 40,000 rubles, with sixty-four permanent and eleven temporary workmen.

The lapidary work of the Ural materials is all executed either at the Imperial Lapidary Works, at Ekaterinburg, or in the vicinity by the lapidary-masters, as they are termed, who employ the workmen or apprentices, each having his own peculiar style. The product of these latter is sold to the dealers at Ekaterinburg, who visit the Nijni Novgorod, Moscow and Ekaterinburg fairs.

The Czars have always manifested great interest in these lapidary works; and at Ekaterinburg is still on exhibition, preserved in a glass case, the cutting-tool used by the Emperor Alexander I, who worked here more or less, and became quite an expert lapidary.

A training-school connected with these works was started in 1877. At present there are fifty-five boys as pupils, who draw and design for nine months in the year, from nine to eleven o'clock, have one hour for recreation, and then model till two o'clock. The graduates have the option, either of remaining as lapidaries in the Government works, or of becoming master-workmen on their own account.

The lapidary works at Ekaterinburg, founded in 1765, and at Kolivan, in the heart of Siberia, in 1787, are so situated that they have command of an immense water-power by which they are run. These works are on a large scale, so that enormous masses of hard stone can be as readily worked as marble is throughout Europe. Those at Kolivan, in the Government of Tomsk, deal chiefly with stones from the Altai Mountains.

Many of the machines are of a primitive character, and have not been changed during the past century. But the facilities for sawing and for drilling of large columns, for ornamenting or for lightening large masses of stone, for channeling, grooving, polishing, etc., are ingenious, and are manipulated with the greatest skill. The annual product of these two establishments amounts to some $35,000, and is entirely for Government use, either in the palaces and public buildings, or for imperial gifts.

The various forms of lapidary work may be divided into three classes. First, the manufacture of vases, dishes and paperweights, often of large size, but invariably made of jasper, rhodonite, malachite, lapis lazuli, aventurine or the like. When the objects are of malachite or lapis lazuli, the body is made of slate or other readily-worked stone and then veneered with a thin coating of these more precious substances. Jewel-caskets, seals and small charms are made either plain or fluted, or are ornamented with leaves, scroll-work or other devices; also seals and cameo-work, such as animals and busts of prominent persons, as the reigning Czar, Turgenieff, etc.

Second, the manufacture of objects of a peculiar kind of mosaic work, somewhat in the Florentine style, and yet very different, made of such stones as perfectly simulate berries, fruits, leaves or flowers.

The unique feature which distinguishes this work is that while mosaics, properly so called, are flat and inlaid, here the objects are represented in their actual form and size. The favorite designs are fruit groups, which are so accurately matched in color and carved in form that they are exact reproductions in stone of the real fruits, resting upon a dish or pedestal of jasper or black marble. Thus, for raspberries, rhodonite of dark pink color is used; for red or black cherries, a peculiar colored sard and black onyx; for white currants, rock-crystal spheres, slightly smoky, which are cut hollow in the center, and the inner parts are so engraved as to simulate perfectly the seeds. The leaves are generally made of noble serpentine. For grapes, a peculiar-colored sard, black onyx or dark purple amethyst is used; black onyx for blackberries, and a yellow jasper for mulberries; and these fruits are generally massed on pieces of jasper, or placed on jasper dishes, and are marvellous for their exactness as to the color, lustre and form of the natural fruit.

Third, the cutting of facetted stones for jewelry, such as aquamarine, sapphire, ruby, topaz and quartz of various colors, and the royal amethyst from Chitanka and Mursinka.

The Ekaterinburg Lapidary Works at present employ

seventy-five men, receiving 25 roubles per month each ($12.50), and ten boys at from 2 to 10 roubles each per month ($1 to $5). Forty thousand roubles are annually expended here.

In 1830 there were 150 men employed. All the designs for these works are made at Peterhoff. A wax model, the exact size of the object, is made by expert modellers and then handed to the lapidaries to copy. The original designs are returned to St. Petersburg, to remain secret in the cabinet of the Czar.

In August, 1891, there were at least 36,000 poods, or over 1,900,000 pounds, of rhodonite, jaspers of various colors, jade and other allied hard stones, at the Ekaterinburg Works. One single block of rhodonite weighed 1,500 poods, or 54,000 pounds. A mass of Kalkansky jasper weighed 500 poods (18,000 pounds). These may seem immense blocks of stone, but in 1869 a mass of rhodonite was brought to the Ekaterinburg Works weighing 2,850 poods (102,600 pounds). It was transported on immense sledges made of iron and wood, and was drawn by ninety horses, or, more strictly speaking, by thirty troikas tied together, one after the other. These were driven by more than fifty men, who shrieked, whistled, swore and beat the horses, and an entire week was required to transport the stone from the mine at the town of Sedelnikowja, about fourteen miles southwest, to Ekaterinburg, a rate of about two miles a day.

It is only on reaching the finishing-room of the great lapidary works that one realizes the imperial grandeur of what is accomplished here. A pair of magnificent Kalkansky jasper vases and pedestals, measuring six feet in height, occupied the time of half a dozen or more men for six whole years.

In 1840 there was finished a large elliptical jasper vase, now in the Winter Palace at St. Petersburg. It is one meter in diameter, and required just twenty-five years to complete. Time seems to be no object; there is no haste. Everything goes to the Czar, either for the adornment of his palaces or as imperial gifts; and whatever is not up to the standard is sold. The two imperial lapidary works are run at a cost of

80,000 to 100,000 roubles annually, paid from the private revenue of the Emperor.

One of the most remarkable pieces of lapidary work ever attempted is the sarcophagus of rhodonite now in process of making for the widow of the late Czar, Alexander II. The block weighs 800 poods, or 28,800 pounds. This may require at least ten years more to complete. A monument of green jasper was also made for her, which was brought from the Altai Mountains in Siberia.

These establishments have made Russia famous for wonderful objects of this kind, nearly all of which are of imperial character. Among the more notable of these may be mentioned the two vases of Siberian aventurine (oriental sunstone), a quartz containing brilliant spangles of mica, one of which was presented to Sir Roderick Murchison, and is now at the Royal School of Mines, in London, and the other to Alexander von Humboldt, and now in the Mineralogical Museum of the University of Berlin, in recognition of the services done by these two eminent scientists in their travels in the Urals.

Dishes, mantels, tables and other objects made of lapis lazuli and of malachite, are to be seen in the Louvre, at Petit Trianon, and at the royal palaces throughout Europe; and the celebrated columns veneered with lapis lazuli and malachite, over twenty feet high, at St. Isaac's Cathedral, and the immense dishes at the Ermitage and other palaces in St. Petersburg.

The Alexander Column was designed by Montferrand, in 1834, at the command of Emperor Nicolas I. This column, of polished red granite from Finland, is 82½ feet high, 13 feet 3 inches in diameter, and rests on a polished block of red Finland granite, 26½ feet square. It is surmounted by a bronze angel 13 feet high, holding a cross 10 feet high, and crushing a serpent underfoot.

In the porticoes of St. Isaac's Cathedral are over forty-eight polished columns of red Finland granite, 56 feet high and 6·6 feet in diameter, resting on immense steps of polished granite, each of a single piece.

The west entrance of the Ermitage is supported by eight

pilasters, against each of which leans a dark-gray granite polished figure from Sserdobol. Each pilaster is 19·8 feet high, supporting the roof. These are only a suggestion to the wonderful interior,—one hundred and twenty columns, all of which are of marble, granite, jasper or other costly material.

On the Anitschkow Bridge over the Fontanka Canal, St. Petersburg, are four colossal bronze horses after the models of Baron Klodt, of St. Petersburg.

From a careful examination of the Russian gem minerals, namely, amethyst, ruby, sapphire, beryl, tourmaline, colored topaz, chrysoberyl, alexandrite, etc., it is my conviction that they suggest an identity of occurrence in the crystalline rocks with those of Ceylon, Japan and Madagascar, and of Oxford County, Maine.

The finest collections of Russian minerals are in the Imperial Mining School, in the Imperial Academy of Science, and the Kotchubey Collection in St. Petersburg, the Koksharow Collection in the British Museum, the Duke of Leuchtenberg Collection in the Mineralogisches Institute at Munich; and, in the United States, in the collections of Harvard College, Cambridge, Mass., the Field Columbian Museum, Chicago, that of Mr. Clarence S. Bement, and the late W. S. Vaux and Mr. George Vaux, of Philadelphia; also in the American Museum of Natural History, and the School of Mines Collection, New York, and in the National Museum at Washington, D. C.

Finally, a few words may be said as to recent archæological investigations in the Ural region, a great district about which there is yet much to learn; and, although its mines and minerals have been studied so well as to make the memoirs upon them classics for the entire world, the archæology and anthropology are not so thoroughly known.

The low water in the Ural region during the summers of 1890 and 1891 afforded an unusual opportunity of examining the lake and river bottoms of this district. This was improved by the Uralian archæologist, Prof. C. Clerc, my esteemed friend and adviser, who accompanied and guided me on my trip with untiring devotion and courtesy, who

has done much to advance the sciences in the Ural Mountains, and to whom I would here express my sincere thanks. His explorations resulted in the finding of some 60,000 objects in flint, jasper and other stones, some of them evidently of high antiquity. The study of these will probably give us valuable data as to the history of the region from an early date to the present time.

On the crest of a small hill, a couple of miles east of Ekaterinburg, are some very curious and interesting prehistoric localities, known as the Kamennya-palatki, or Stone Tents. These are elevated masses of the stratified granitic rock composing the hill, which have in some manner resisted weathering more than the rest, and now stand out on the summit like low towers or beehive-shaped huts. Their general form, and the strongly-marked horizontal layers of the weathered granite composing them, give them the aspect of half-ruined structures built by man. A few years ago a person seeking for gold or treasure discovered at the base of these "Stone Tents" some remains of ornamented pottery; this led to careful examination by archæologists; and there have since been obtained, beneath, around and on the top of them, many interesting objects, indicating that these singular natural formations were a favorite resort of men in prehistoric times. Dr. Clerc, who has written and published largely in regard to them, suggests that they may have been used partly as places of sacrifice and partly as lookouts or watch-towers. He even inclines to the belief that man has aided nature somewhat in shaping them into their peculiar forms. The objects found include ornamented pottery, stone implements, a rock-crystal bead and fragments of bones. The further discovery of a small bronze arrowhead in the vicinity, associated with remains otherwise similar, leads M. Clerc, with M. Malakhoff and others, to assign the whole to the close of the neolithic period, when bronze, although known, was still rare and valuable. Other similar natural structures, some of larger size, occur at several points in this region, and have yielded similar traces of having been long frequented for some purpose by prehistoric men.

Mining and Metallurgical Section.

Stated Meeting, May 11, 1898.

OLD AND NEW METHODS APPLIED IN PLANNING PIPE-LINES AND PENSTOCKS.

By F. M. F. Cazin, Hoboken, N. J.,
Member of the Institute.

[*Concluded from p. 192.*]

It being known that $H'' < H' < H$, there must be an inversely proportional relation between values in which these values H'', H' and H take the place as divisors. Hence,

$$\sqrt[4]{\frac{h}{H''}} > \sqrt[4]{\frac{h}{H'}} > \sqrt[4]{\frac{h}{H}}$$

and in consequence $D'' > D' > D$.

This result may be expressed in words as follows:

II. *The diameters of the pipes, at any level of the supply-pipe line, may* (in order to permit the body of water to descend at uniform rate through the entire length of the pipe, or to descend in unimpeded adaptation of its shape to the laws of gravitation) *be decreased at the rate of the fourth root of the head above such level increases, the required diameter being in all cases as*

$$D = d'' \cdot \frac{\sqrt[4]{h'}}{\sqrt[4]{H'}}$$

It may then be mentioned that, whenever there is in a pipe line an upward bend, by which the head, and consequently the velocity of movement, is intermediately decreased, the upward bend requires an increase of diameter, as the increase of head admits of a decrease of diameter. (See *Fig. 2.*)

In the form of the equation that contains the coefficients h and H, heads, in fact, are exclusively considered, and no

doubt remains as to what these values stand for; but in the form of the equation that contains v and V as coefficients, doubt may exist whether velocity in fact and as experimentally ascertained be meant, or theoretical velocity under any surveyed head be intended.

It therefore appeared as preferable to express the stated law on the basis of the undoubtful values h and H for surveyed heads as conditional to theoretical requirement.

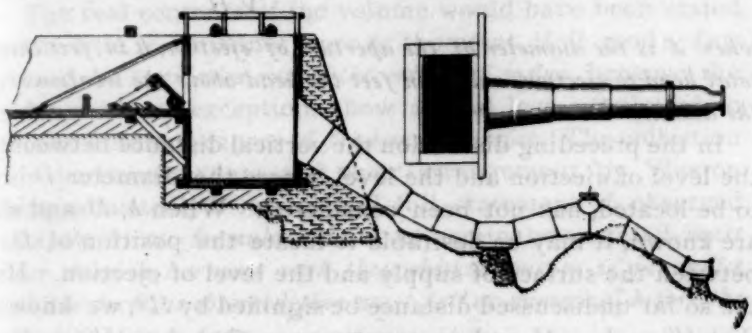

FIG. 2.

The diameters of pipes and of their inlets, at any vertical distance below the surface of the entering liquid, as required for imparting to them sufficient width for permitting a stated volume, weight or body of liquid to fall in the shape that it would assume if free to fall in adaptation to the laws of gravitation.

III. *The orifice of a supply-pipe, intended to eject a circular current of a diameter d inches, under a head of h feet, which orifice is at a vertical distance of H feet, below the surface of the inflowing liquid, to permit inflow in the same quantity, as will, with unimpeded flow, be ejected, must be as*

$$D'' \text{ inches} = d \text{ inches} \cdot \frac{\sqrt[4]{h}}{\sqrt[4]{H''}}$$

IV. *The diameter of a supply-pipe at any level, intermediate between the level of ejection and the surface of the supply-liquid, to secure unimpeded flow under the laws of gravitation, must be as*

$$D \text{ inches} = d \text{ inches} \cdot \frac{\sqrt[4]{h}}{\sqrt[4]{H}}$$

when H feet is the difference in feet in level between the surface of inflowing supply and the level of D, and h in feet is the total head, under which ejection takes place from an aperture of the diameter d inches.

V. *To permit natural flow within a supply-pipe, it must, at any level above that of final ejection, have a diameter equal to*

$$D \text{ inches} = d \text{ inches} \cdot \frac{\sqrt[4]{h}}{\sqrt[4]{H}}$$

when d is the diameter of the aperture of ejection, h in feet the total head to ejection, and H in feet the head above the location of the diameter D.

In the preceding discussion the vertical distance between the level of ejection and the level, where the diameter D is to be located, has not been considered. When h, D and d are known, it may be desirable to locate the position of D, between the surface of supply and the level of ejection. If the so far undiscussed distance be signified by $H°$, we know that $H° = h - H$, and in consequence, that $h = H° + H$.

The general equation may, therefore, be expressed in the equivalents for

$$D = d \cdot \sqrt[4]{\frac{h}{H}} = d \cdot \sqrt[4]{\frac{H° + H}{H}} = d \cdot \sqrt[4]{\frac{H°}{H} + 1} = d \cdot \sqrt[4]{\frac{h}{h - H°}}$$

and

$$\left(\frac{D}{d}\right)^4 = \frac{h}{H} = \frac{H° + H}{H} = \frac{H°}{H} + 1 = \frac{h}{h - H°}$$

and

$$H = \frac{h}{\left(\frac{D}{d}\right)^4} = \frac{H° + 1}{\left(\frac{D}{d}\right)^4}$$

and

$$H° = h - \frac{h}{\left(\frac{D}{d}\right)^4}$$

Therefore d, D and h being known, the location of D may be ascertained by determining the values for H and $H°$.

Other investigators have approached the problem that has been discussed in the preceding lines on exclusively empirical lines.

They have experimented with supply-pipes and have compared theoretical efficiency with the results of their observations.

All of moment that has been achieved in this empirical line of research has been collected in an interesting and meritorious little volume: Tables, showing *loss of head*, due to *friction* of water in pipes, by Edmund B. Weston, C.E. (N. Y., 1896.)

The real contents of the volume would have been stated on the title in a manner more to the point, if it read: *Loss of head due to friction and to the orifice of influx*, because the tables, without exception, show a total loss, attributed to the two different causes of *friction* and *orifice*. The collection of experimental data and their arrangement by Weston being admittedly a correct and full statement of observed facts, *the by me formulated laws*, as hereinabove stated, *must either stand in harmony with these observations, or if in conflict with the facts, as observed, they must fall as chimerical before the authority of such facts.*

It would not do, in connection with a law deduced from the very nature of things, to claim "that the same formula would not apply to all cases," notwithstanding the fact that Weston advances such a claim, for all that, which the science of hydraulics has offered up to date towards solving the question under investigation. Weston frankly admits (page III) that "a general formula was not discovered which would satisfactorily apply." *He, nevertheless, quotes three different equations and declares them as normally applying to three different modifications of solid faces on which the liquid slides. Two of these equations originated with the French savant, H. Darcy, and the third one with Weston himself.

Weston's formula, applicable to smooth pipes, and to pipes that do not exceed 3·5 inches in diameter, is as follows:

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*Blaine, R. G., *Hydraulic Machinery*, 1897, p. 54: "Sufficient data for accurately determining the flow of water in large pipes are not yet available. It is best to allow a margin for excessive friction and to guard against repeating such an expensive mistake as that made recently at Newark (East Jersey Water Co.), where about 21 miles of riveted steel mains have to be duplicated."

$$H = \left(0{\cdot}0126 + \frac{0{\cdot}0315 - d\,.\,006}{\sqrt{v}}\right) \cdot \frac{l}{d} \cdot h$$

in which formula d, h and v are used as commonly used, l designating the length of pipe in feet, and H the loss of head in feet, due to friction.

The other loss of head, *due to influx*, is stated by Weston to be correctly stated by a reducing coefficient = 0·505.

Empirical investigation has been conducted on the very fundamental assumption that a pipe only of many times the diameter of the aperture of ejection be fit to feed such ejection in such quantity that the discharge represent a full benefit of the actual head. Pipes discharging from an aperture of their own uniform size showed a loss of efficiency, or, as commonly called, of head, which loss amounted all the way from 90 per cent. to many times the theoretical effect of the head in fact.

So far, it has occurred to nobody, except to myself, to inquire into the conditions of free and unimpeded fall and flow of liquids in pipes, and engineering practice in this matter contented itself with testing efficiencies, the same as the English Admiralty contented itself in matters of nautical construction with testing the resistance to models of men-of-war, until a law for measuring such resistance, by the simple means of the quotient of the length in metres on the ship's water-line in the displaced weight was discovered by the author. (Compare the *Journal of the Franklin Institute*, March to May, 1893.)

Setting aside the placid submission to an experienced evil, the author's inquiry has been directed to an obviation of the same and to the avoidance of using unnecessary and excessive sizes of pipes.

Even Rankine has never abandoned the older views as stated. In his latest supplementary statements he yet (to Article 646) states: "The loss of head, due to the resistance to the flow of water in a pipe, arises mainly from friction." There is no mention of resistance consequent to the shape of pipe, forcing the water to flow in another shape than the one that it would and must assume, if free to so do, under the eternal laws of gravitation.

The nearest approach to a progressive conception of the problem in hand may be found in Rankine's statement (same supplement) that if the form of the mouth-piece be that of the *contracted vein*, the resistance at entrance of pipe be insensible. But in his explanation of that, which he refers to as "contracted vein" (Article 627), he does not, as I do, stipulate any law by which the shape of mouth-piece as well as pipe may be determined, but refers to an entirely different point of consideration, namely, the contraction of a free jet, after leaving the aperture of ejection, as discussed by Poncelet and Lesbros, on an exclusively empirical basis, the same as that on which the entire question, now under consideration, has invariably been treated.

While in Weston's tables the *loss* of head, due to *orifice of influx*, is invariably stated, as equal to 0·505 . *h*, the *loss* attributed to *friction* on pipe-walls appears as averaging in excess of 0·4 . *h*, while the total average of losses appears as 90·557 per cent. of head.

We also find in Weston's book the assertion repeated, that "friction is directly and simply as length." Up to date, this proposition has been understood to the effect that the increase in length of a supply-pipe called for a proportionate increase of width. The more rational interpretation, as supported by the new method of dealing with the problem, is evidently to the effect that provision for counteracting the effect of friction should extend over the entire length of the pipe. On this more rational interpretation my proposition for a lubricating liquid shell is based, the execution of which must of necessity take shape in an increasing stable coefficient to the diameter *D* on the entire length of pipe, the amount of which coefficient will have to be established by virtue of prevailing conditions, and will be discussed here below.

With an understanding about the variance in conception, as submitted in the preceding lines, we are prepared to test the new proposition by the results of observation, as collected by Weston.

The *loss* of head in feet, due to the *orifice of influx*, has been assumed in Weston's Tables, as already stated, as of uniform value, namely as 0·505 of the head.

The *loss* of head in feet, due to *friction* is stated, amongst others, as follows:

In pipes of ½-inch diameter as—

Loss	1·0352	1·9725	2·7548	3·633	4·4048	15·7335
Head	2·03	4·15	5·98	8·14	9·97	39·26

to which fractions the following figures are equivalents:

Loss	0·51,	0·475,	0·46,	0·446,	0·442,	0·4, to which must be added as loss in inlet—
Head	0·505	0·505	0·505	0·505	0·505	0·505
Total loss	1·015	0·980	0·965	0·951	0·947	0·905

The loss attributed to *friction* averages in the six quoted cases as 0·4555, and the general average of losses is, in consequence, as 0·9605 . *H*.

Applying the newer conception to these cases, the inquiry would be directed first towards finding the dimensions of the orifice of influx that would permit to a 2-inch aperture of ejection the full benefit of head, as against the older conception, ascertaining the loss resulting from uniform size of inlet and pipe, which amounts to 0·505 . *H*.

A precise answer is given to this inquiry under the newer method, to the effect that the requirement in diameter of orifice of influx is absolutely dependent on the head above such orifice, as no influx can take place without such head, and that the lower such head, the wider the orifice should be. A precise answer can only be given when a precise head above such orifice is assumed.

The equation for *D*, when the value for *H* be as *O*, reads

$$D = \sqrt[4]{\frac{h}{O}} \times d$$

a product in which one factor is of unlimited greatness.

The true interpretation of this result is two-fold, namely:

(1) No orifice of inlet suffices between which and the supply-surface there is no difference of level.

(2) The equation gives evidence of its own validity, even though the case may pass out of the realm of elementary mathematics.

Assuming the said head to be 1 foot = H'', then

$$D'' = d \cdot \sqrt[4]{\frac{h}{H''}} = d \cdot \sqrt[4]{\frac{h}{1}} = d \cdot \sqrt[4]{h}$$

Selecting one of the cases coming nearest to the average of general loss, say the fourth in the row, as quoted, the applied equation reads:

$$D'' = 0{\cdot}5''. \sqrt[4]{8{\cdot}14} = 0{\cdot}5''. 1{\cdot}69 = 0{\cdot}845''$$

The relation between area of actual to required orifice then appears as $0{\cdot}5^2 \div 0{\cdot}845^2 = 0{\cdot}25 \div 0{\cdot}714$, the actual area being only

$$\frac{0{\cdot}25}{0{\cdot}714} = 0{\cdot}35$$

and the loss being in the case as assumed as $1 - 0{\cdot}35 = 0{\cdot}65$, in place of 0·505 as assumed by Weston.

But assuming the orifice of influx to be 2 feet below the surface of the supply, then the required diameter of orifice appears as

$$D' = d \cdot \sqrt[4]{\frac{h}{H'}} = 0{\cdot}5'' \cdot \sqrt[4]{\frac{8{\cdot}14}{2}} = 0{\cdot}5 \cdot \sqrt[4]{4{\cdot}07} = 0{\cdot}7102$$

The proportion between areas then appears as:

$0{\cdot}5^2 \div 0{\cdot}7102^2 = 0{\cdot}25 \div 0{\cdot}5044$, the actual area being only

$$\frac{0{\cdot}25}{0{\cdot}5044} = 0{\cdot}495$$

and the *loss* due to *orifice of influx* appears as $1 - 0{\cdot}495 = 0{\cdot}505$, or precisely the same as Weston states it, as the observed result of many tests. Pity it is that the experimenter has not stated the head above orifice, which statement would have furnished still further experimental corroboration for my new conception of the problem of adapting the dimensions of pipe-lines to the conditions as given by head and quantity of discharge demanded.

It now remains to also compare the empirical results concerning loss of efficiency in pipes, collected in Weston's Tables, and attributed to *friction*, with the results obtainable by means of the laws as hereinabove evolved and pronounced.

These laws would meet neither doubt nor contradiction on the part of hydraulicians, were it not for that ominous word "*friction.*" The main destiny of the word has been to confuse observations and conceptions, which without its use might have been precise and clear. No other word in technics and science has served as a symbol of misconception to the same degree as this word "friction" has. And never has misconception been adhered to with firmer tenacity than the misconception of friction. It is, nevertheless, inopportune to largely discuss this question of friction, and even as a matter of convenience, I propose on this occasion to be content with discussing the antidote of friction, namely, lubrication, in connection with water flowing in pipes. (Compare "Resistance to Ship's Motion," by the same author, *Journal of the Franklin Institute*, March, 1893, page 205, etc.)

Having ascertained what space a falling body of water requires for its unimpeded fall within pipe-lines, the author proposes to surround the falling body with a lubricating shell of water that does not fall. Water will then move within water, and the friction will not be in excess of what it is when a smaller current moves within a larger body of water. Prony, the inventor of a friction-dynamometer, which has contributed more than any other cause to discrediting the prevailing conception of friction, has established an empirical coefficient of loss for such inter-liquid friction, applicable to natural velocity (compare Rankine, Manual, Art. 640) as

$$\frac{v + 7{\cdot}71}{v + 10{\cdot}25}.$$

If Prony's estimate of such effect of inter-liquid friction were correct, it would evidently be applicable inversely in increasing the diameter of pipes, based on the velocity of the liquid; and in place of

$$D = d \cdot \frac{\sqrt{v}}{\sqrt{V}} = d \cdot \frac{\sqrt[4]{h}}{\sqrt[4]{H}}$$

the equation for diameter should read as

$$D = \frac{\sqrt{v + 10{\cdot}25}}{\sqrt{V + 7{\cdot}71}} = \frac{\sqrt[4]{h + 10{\cdot}25^2}}{\sqrt[4]{H + 7{\cdot}71^2}}$$

Modern conception of correct measurement of friction excludes the velocity of motion in contact-faces as an element in such measurement, and considers weight and its expression: pressure, as the main element in such measurement. In the case under consideration the constantly increasing velocity is a direct expression of the effect of weight, when free to fall, and is the only expression in the equation that represents weight.

Therefore, as far as the modern conception of friction is concerned, the application of a corrective in the shape of inversed effect of friction, to the value of current-area or of current-diameter of section, could not be objected to. Nevertheless, such corrective in the form proposed by Prony is absolutely inapplicable, because it inevitably leads to absurd and impossible results, as any calculation based thereon will demonstrate.

In this connection it may be opportune to also quote Rankine's expressions (Art. 639), as follows:

"The friction of a stream against its channel 'causes' not merely retarding of the film of fluid, which is immediately in contact with the sides of the channel, but a retarding of the whole stream, so as to reduce its motion to one approximating to a motion in plain layers, perpendicular to the axis of channel."

Although this effect, as by Rankine described, is in fact and precisely the effect of impeded formation of the liquid body in its descent, such as adaptation to the laws of gravitation would produce it, he had not in mind such real cause of the described effect, namely, the enforcement of a uniform velocity of fall in pipes of uniform size, and the consequent formation of horizontal layers, as against the natural velocity, that increases at the rate of the square of the distance of fall, and its effect of contracting the falling liquid body as fall proceeds.

The admission by Rankine (Art. 625), that "single layers move with uniform velocity," is equivalent to the admission by the celebrated scientist, though inadvertently, that a retarding effect, otherwise attributed to friction, may more correctly be attributed to the resistance offered to the

motion of the liquid by a form of channel, which is not in full adaptation to the form assumed by the liquid body under the laws of gravitation, as the consequence of continuously changing natural velocity. That *in a pipe of uniform section but one velocity can prevail from end to end* is a natural conclusion from the generally accepted condition of cross-current layers moving with uniform velocity. This then means, in fact, that in pipes of uniform section the liquid body is forced to fall with uniform in place of increasing velocity, and in consequence forced to undergo inter-liquid friction between all of its parts, while with a channel adapted to the natural requirement, as established by the lengthening of body under increased velocity, the body that changes position within a second for the distance, as indicated by velocity, being considered as the moving body (= $Q\,y$), such interior friction is not one that resists to gravitation, but is in harmony with the effect of gravitation, and in consequence reduced to a minimum. Obviating excess of interior friction, there remains only the friction against the walls of the channel, and as in pipes of excessive width throughout, a shell of water may perform the function of a lubricator to a falling liquid body that has sufficient space to develop and fall in its natural shape. To establish the diametrical requirements, therefore, is equivalent to the finding of the limit (*justemilieu*) between excess and deficiency in size of supply-pipes intended for a given capacity.

In the preceding lines it has been demonstrated, in regard to *loss of head* attributed to *orifice of influx*, how closely the results of the newly-proposed equations for determining the diameter of such orifice coincide with the facts as collected in Weston's Tables. It is immaterial to which part of these tables the new equations be applied; the same results, when properly applied, will be evolved. To repeat these calculative tests would unnecessarily intrude on the valuable space of this publication. But it remains to repeat the same demonstration in regard to the *loss of head* attributed to the effect of *friction* within the pipes or against their walls. In such renewed demonstra-

tion it will be most to the point to follow out the same case as considered in regard to loss in orifice of influx.

We have had under consideration a pipe of uniform ½-inch diameter, ejecting under head of 8·14 feet. We have in regard thereto established the necessity of a 3-inch orifice of influx, if situate 2 feet below surface, in order to secure the possible ejection of the maximum quantity that may be ejected from the ½-inch aperture under the stated head.

We may now assume that the orifice of 3-inch diameter be contracted to the ½-inch uniform diameter of the pipe at a vertical distance below of 6 inches. And we may inquire into the effect of such contraction.

The head above such contraction is as $2' + 0{\cdot}5' = 2{\cdot}5' = H$. The head above the level of ejection is $8{\cdot}14 = h$.

The required diameter (D) to permit unimpeded motion of liquid body, as ejected per second from the stated aperture under the stated head, is shown by the equation:

$$D = \sqrt[4]{\frac{h}{H}} \cdot d'' = \sqrt[4]{\frac{8{\cdot}14}{2{\cdot}5}} \cdot 0{\cdot}5'' = 0{\cdot}672$$

We then have the proportions of real to required section as

$$\frac{0{\cdot}5^2}{0{\cdot}672^2} = \frac{0{\cdot}25}{0{\cdot}45} = 0{\cdot}55$$

And the loss of effect is as $1 - 0{\cdot}55555. = 0{\cdot}44444$.

We find in Weston's Tables this loss within pipe stated as amounting to 0·446, the difference, inappreciably small as it is, being attributable to neglect of decimals.

It seems to be entirely superfluous to carry the demonstration any further. What has been shown appears to be sufficient to convince us of the fact that the loss attributed to friction and to orifice of influx is really a loss consequent to the same cause, namely, the lack of space in a pipe of uniform section, for the free development of form of falling liquid body, as it would assume, under the laws of gravitation, if its movement were unimpeded, and that such loss can presumably be obviated by adapting the form of supply-pipes to the dictation of nature, viz.: under the equations as hereinabove developed.

While the loss attributed to friction is not, as such, so attributable, it is wise to provide against any minor loss so attributable.

Whenever the diameter of penstock or pipe-line is in excess, on their entire length, of that which the unimpeded movement of the liquid body demands, then such excess provides for the liquid lubricating shell, as hereinabove mentioned. Such excess assumes the form of an increasing coefficient to the value of the rational pipe diameter; and experiments have demonstrated the fact that in available sizes such a coefficient = 1·1. covers the requirement when applied to pipes that have the rational diameters as conditioned in the stated equations, which will then read:

$$D''' = 1{\cdot}1. \sqrt[4]{\frac{h \text{ feet}}{H \text{ feet}}} \cdot d''$$

H signifying the head above the level of D, and h signifying the head above the level of ejection.

The only variable value in the equation is the coefficient 1·1, which may find closer adaptation to qualities of interior pipe wall, though within very narrow limits only, on penalty of permitting excess in size over and above practical requirement.

Nought of importance remains but to speak of the practical economy or saving in first cost resulting from planning penstock and pipe-lines under the more modern conception of the problem, viz.: by the stated equations, whenever the required discharge per second or the section of total ejectable current and the available head are known.

It is evident, from the very figures as shown, that, for a specified discharge, we find, on the one hand, the necessity, when using pipes of uniform section, to provide for losses in efficiency, amounting to from 90 per cent. to many times the total maximum efficiency of a pipe of the same section as that of the aperture of ejection. In consequence, we are compelled to use pipes the size of which, from end to end, is largely in excess of that which is needed. On the other hand, we find in the author's newer devices, first invented to meet a practical requirement, and as such protected by

granted patent-right, and later on proven correct by mathematical evolution, that we can economize in first outlay to the extent of a major part by adapting successive sizes inversely to increasing velocity of fall, or to the real nature of the requirement. The illustrations are intended to indicate the new device. Specific estimates of comparative costs will be published on a later date.

Stated Meeting, April 13, 1898.

THE REDUCTION WORKS FOR SILVER ORES AT ADUANA, SONORA, MEXICO.

By MILTIADES TH. ARMAS,
Formerly Assistant Superintendent.

The Quintera Mine of the Alamos district in Sonora, is a powerful silver-bearing lode, known as the "Quintera" lode, and to-day is the only one in that section of the country which, notwithstanding the complexity of the ore, is worked profitably.

With a general course nearly due north and south, and a dip of 16° from the vertical towards the west, this lode traverses the crest of the Quintera Mountain.

Flanked east and west by higher and more rugged peaks, this mountain forms the divide, or pass, over which a bridle path connects the mining towns of the two leading mines, viz., Aduana on the northern side, where the reduction works of the Quintera Mine are situated, and Promontorios on the opposide side, with the reduction works of the Almada and Tirito mines.

The population of Aduana, Promontorios and the neighboring settlement of "Minas Nuevas" is made up of native Mexicans mostly of Indian blood.

Besides being very docile, they become excellent mine and mill operatives. The pure-blooded Indians appear to me to be the best of all.

In this part of Mexico its cheapness goes far toward off-

setting the evils which may be considered to attend the pursuit of mining or milling by foreigners.

Six miles from Aduana is Alamos. This is one of the most important towns in Sonora, and is connected with Aduana by a wagon road, which continues seventy miles to the port of Agiabampo, on the Gulf of California.

This brief geographical description, with some additional information concerning the system of weights and mode of transportation, will probably render clearer the description of the various methods applied at the reduction works of silver ores in Aduana.

Notwithstanding the adoption of the metric system by the Mexican Government, in all its official transactions, the people at large still adhere to the old Spanish measures.

In mining districts the unit is 300 pounds (1 pound = 460 grams), or the weight that a mule can carry comfortably, since the principal means for transportation is by mules.

The natives speak, as a rule, of so many ounces per cargo of 300 pounds. (1 ounce = 28·76539 grams.)

A description of the divers kinds of ore obtained from the same lode, with an average composition of each kind, will now be considered.

The admixture of ore is complex and varies in quality according to the relative proportions of its several minerals. All is hand-picked and hammer-dressed, and assorted into several grades, according to the degree of concentration of its metalliferous contents, or to the predominance of certain ingredients. This work is done at the mine by boys called "pintistas."

Smelting Ores.—A. Argentiferous gray copper, carrying some blende and galena. The practical yield in silver of ores of this class is from 350 to 600 ounces per ton.

ANALYSIS.

	Per Cent.
SiO_2	36·2
Cu	11·4
Pb	9·8
CaO	1·8
Fe	2·1
S	10·8

	Per Cent.
Zn	11·5
Sb	6·3
As	5·2
As_2O_3	1·2
Ag	2·4

B. Black Ore—Prieta II.—A complex variety, made up of galena, blende, copper glance, chalcopyrite, with arsenical and antimonial sulphides, all more or less argentiferous, and containing occasionally some stephanite. Their yield in silver is from 200 to 400 ounces per ton.

ANALYSIS.

	Per Cent.
SiO_2	41·4
Cu	11·4
Pb	9·8
CaO	0·8
Fe	3·1
S	11·3
Zn	13·2
Sb	4·2
As	3·3
Ag	1·07

C. Plomosos.—The same as black ore, *B*, but with a predominance of galena. The grade of silver in these ores is inversely proportional to the quantity of galena, and as a rule varies between 60 to 200 ounces per ton.

COMPOSITION.

	A Per Cent.	B Per Cent.
SiO_2	33·2	33·0
Pb	30·6	28·1
Cu	6·8	8·0
Zn	11·5	16·3
S	12·2	11·1
Sb	2·1	1·2
As	2·6	0·9
Ag	0·6	0·88

D. Milling Ores.—Mostly ores yielding between 48 and 72 ounces per ton, and in which the blende predominates.

COMPOSITION.

	Per Cent.
SiO_2	66·20
Al_2O_3	0·30

	Per Cent.
Fe	4·00
CaO	1·80
MgO	traces
Zn	9·35
Cu	3·82
S	6·76
Pb	4·60
Sb	1·20
As	0·84
Ag	0·22

E. Concentration Ores.—Various ores, but of a tenor in silver of 23 ounces per ton, and which are never allowed to pass 27 ounces per ton.

As a rule the gangue is quartz or mother rock, mostly decomposed. The lode being a contact formation, is between two massifs of rhyolite and trachyte.

The sorting of the lixiviation ore requires particular care so as to avoid all kinds of decomposed rock or gangue, which is liable to interfere in the subsequent treatment of the ore by lixiviation by forming a kind of clay impeding the rapid filtration. Pure quartz, on the contrary, is rather helpful, as we will see further on.

The reduction works are about a mile from the mine, the former being situated at the foot of the hills, and on the banks of a rushing stream, which, however, is mostly dry during the dry season. The transportation of the ore is done by mules at 18½ cents (Mexican money) per cargo.

HACIENDA DE BENEFICIO—"DIOS PADRE."

The Mill.—The lixiviation and concentration ores are treated directly by 20 stamps. Ten stamps are employed for the dry crushing of the lixiviation ore.

The following are the data of the 20-stamp battery:

TWENTY-STAMP BATTERY.

Stem	3″ x 13′ 6″	320 lbs.	
Tappet		147 "	
Head		220 "	
Shoe		126 "	
		—	813
Die	75	— 86 "	
Cam		245 "	

Cam-shaft for 10 stamps	5½″ x 14′ 7″
Cam-shaft pulley	1,650 lbs.
Number of revolutions of the cam-shaft per minute	54
Number of drops per 1′	105
Fall in feet	0′·5
Mortar block	16″ x 20″ 30″
Horse-power for 20 stamps	30

At first the pulp passed through a 30-mesh screen, but it was noticed that the lixiviation of the chloridized ore was not rapid. The filtration becoming slow, the dissolved silver probably was reduced and precipitated by prolonged contact with the sulphides of zinc and lead, or even by their sulphates, which always occur in the chloridized ore.

It was therefore necessary to resort to a 16-mesh screen, and the results have been highly satisfactory.

The pulp is conveyed by a belt-elevator to a bin, from which the four roasting reverberatory furnaces are charged.

Roasting and Chlorination Reverberatory Furnaces. — The reverberatory furnaces are of the well-known type with four graded hearths. Dimensions: 14 x 9 feet.

The ore remains at each hearth two hours, and at the last two is continually stirred. Certain kinds of ores, especially sulphides (lately we were treating ores containing mostly blende), rich in antimony, etc., require more time, as the roasting has to be done at a very low temperature in order to avoid volatilization.

The blendiferous ores, whose analysis I have given, required three hours at each hearth, *i. e.*, twelve hours in total, the charge being 1,200 pounds.

At first, half of the necessary salt was added at the battery and the other half in the last hearth, but experience showed that it was better to add all the salt at the last hearth two hours before discharge.

The quantity of salt added varied between 4 per cent. and 8 per cent., according to the nature of the ores. At the beginning, when nothing but green ore (chrysocoll) had to be treated by lixiviation, a great deal of difficulty was encountered in the chlorination. Soon, however, we found that the sulphides existing with the green ore were in small quantities, and a great part of their sulphur was volatilized;

consequently the sulphates formed were insufficient, and required a great deal of time to be converted into that state in order to attack the salt. So we resorted to the addition of 1 per cent. of pyrites. Pyrites, as it is well known, readily loses half of its sulphur and then is rapidly converted into sulphates necessary for the production of chlorine. Even with blendiferous ores pyrites was found to help chlorination very much. With the above-mentioned green ore and the addition of the pyrites, the time of roasting and chloridizing did not exceed eight hours, and the percentage of chlorination was on an average of 97·5 per cent. Attention should be directed to the fact that in all kinds of ores, when very siliceous, we found that the chlorination was rapid and more nearly perfect.

It can be probably ascribed to the following reaction:

$$ROSiO_2 + 2NaCl = Na_2OSiO_2 + Cl_2$$

The wood which we preferred for the purpose was "torrote" and "piojo," because they produce a large flame and have a great deal of moisture, the conversion of which into steam facilitates so much the chlorination.

Labor.—All the men employed at these furnaces are pure Maya Indians, and it can safely be said that this kind of work is their specialty.

For four reverberatory furnaces there are employed:

2 foremen at $1.25	$2.50
24 ore stirrers at 75 cents	18.00
10 ore chargers, wood transporters, etc., at 75 cents	7.50
1 salt transporter at 40 cents	.40
	$28.40

The chloridized ore is discharged on a cooling floor in heaps, where the chlorination is still continued, as always some chlorine remains with the chloridized ore at its discharge.

Lixiviation—Charging the Vats.—The charging of the vats is done on contract work by four Indians. The tailings are loaded on mill dump cars and dumped into the "arroyo." The filter is repaired, and the ore which has been previously

slightly moistened and the lumps broken up is taken from the cooling floor and charged.

If the chlorination was properly accomplished, the ore at its discharge from the furnace will have a very strong odor of chlorine and change rapidly its color from dark brown to ochre, owing to the reduction of the perchloride of iron into sesquioxide; when slightly moistened it must assume a spongy appearance, and finally when pressed in the hands it must not become muddy or adhere to the hand.

These characteristics are essential to the good working of the lixiviation, and the Indians in charge of these works are well acquainted with these details.

This ore is charged up to the brim of the vat, because on lixiviating it will settle down to a foot or more below the brim.

There are nine vats.

DIMENSIONS OF THE VATS.

	Feet.
Diameter	20
Height	5
Height of filter	1

Filter.—The filter is the well-known one, composed of stones at the bottom, with sand and gravel on top; it does not exceed one foot in thickness.

The reduction works have nine vats of a capacity varying from 37 to 47 tons, according to the nature of the ore treated.

The lateral discharge of the lixivium is preferred, as it avoids obstructions.

All the vats are in a row and their rubber discharge pipes lead to a wooden trough, which in turn carries all the silver-bearing solution to the three precipitation vats. By its side is another trough for conveying the washings of the base metals of the ore to the cementation vats for copper.

Leaching.—Once the vat is charged with the ore, water is admitted from below through the same discharge outlet. The main object of this is to expel the imprisoned air and have the ore more evenly settled. When the water reaches the top of the vat, then it is admitted from above, and the rubber discharge pipe is directed to the base metal solution

trough. This solution contains mostly sulphates and chlorides of copper, zinc, iron, etc. The recovery of the copper and the little silver that might have dissolved will be the subject of another chapter.

The length of time for the removal of the greater part of the base metals through water lixiviation varies considerably, and it often requires between fifteen and twenty-four hours. When calcium polysulphide does not produce any precipitation or a very slight one, it indicates that most of the base metals have been removed, and then half of the water is allowed to run out and the calcium hyposulphite is allowed to take its place. However, before admitting this solution, the cracks and interstices formed on the surface of the settled ore, and which are liable to offer an easy outlet for the solution, are filled up by plunging around them with a shovel.

The demarkation of the substitution of the water by the hyposulphite of calcium solution has a sweetish taste, and it requires the special attention of the foreman so as to divert, in due time, the flow to the argentiferous solution trough.

The rate of filtration is a variable one, $2\frac{3}{16}$ inches being considered a good one.

DATA ON LIXIVIATION, DURING OCTOBER, NOVEMBER AND DECEMBER, 1897.

Number of Operation.	Name of Vats.	Date of Charging the Vat.	Date of Discharging the Vat.	Initial Grade of the Ore Per Ton.	Insoluble Per Ton.	Tailing Per Ton.	
714	*A*	Oct. 3	Oct. 12	46·1	1·9	1·3	
715	*C*	" 6	" 22	52·6	1·9	1·9	
716	*H*	" 8	" 26	12·3	1·9	3·2	Old Tailings.
717	*B*	" 9	" 16	48·7	2·6	1·9	
718	*A*	" 12	" 23	40·9	0·6	4·5	
719	*I*	" 14	" 30	14·3	2·6	3·2	Old Tailings.
729	*A*	Nov. 5	Nov. 20	61·1	2·6	3·2	
730	*C*	" 9	Dec. 9	58·5	1·3	3·9	
738	*D*	Dec. 1	" 17	50·7	1·3	1·3	
740	*F*	" 7	" 17	46·8	1·9	1·9	
743	*E*	" 15	" 30	49·4	1·9	2·0	
747	*B*	" 23	" 31	46·8	3·2	2·6	

A sample of the ore after charging the vat is taken, and also a sample of the tailings, and assayed.

All the argentiferous solutions by the common trough, are carried alternatively to three precipitation vats of 12 x 6 feet and 678 cubic feet capacity. There the silver is precipitated by a solution of polysulphide.

It often happens that by some cause part of the chloride of silver is reduced or otherwise acted upon, and becomes insoluble in the hyposulphite of calcium solution; we found that by discharging the vat and leaving the ore exposed to atmospheric effects for a certain length of time, the silver becomes soluble and could be leached again with better success. This can be seen in the table of lixiviation.

(Operation No. 716, vat *H*. Operation No. 719, vat *I*.)

Mr. Nute, superintendent of the neighboring English mine, at present treats the old tailings, which his predecessors discarded, and which have been exposed for many years to atmospheric action, with a good margin of profit.

The chlorination and lixiviation cost is $17.87 per ton.

Hyposulphite Solution.—This solution is practically that of double hyposulphite of calcium and sodium, most of the sodium hyposulphite being converted into that of calcium by the well-known reactions of polysulphide of calcium on hyposulphite of silver.

Divers experiments carried on for a considerable length of time proved that the best strength was between 0·55 per cent. and 0·60 per cent., as a stronger solution dissolved the remaining base metals of the ore, which at the precipitation vats rendered the precipitate a serious difficulty, to say nothing of the lowering of the grade of the silver sulphide.

A daily determination of the strength of the solution is a matter of a few minutes, by a standardized solution of 5·121 grams of iodine into 7 grams of potassium iodide, the reaction being the following:

$$2Na_2S_2O_3 + 2I = 2NaI + Na_2S_4O_6.$$

Precipitation of Silver.—The precipitation of silver is done with a calcium polysulphite solution. Care must be taken to avoid an excess of the said solution, as it will cause pre-

cipitation of the silver in the leaching vats when the hyposulphite solution is decanted and used over again.

In practice they add calcium polysulphide until a few drops of it in a glass of the argentiferous solution produces a milky appearance. It is always preferable to have too little than too much calcium polysulphide in the hyposulphite solution. After stirring it with a wooden stirrer the precipitate is left to settle and the solution decanted by means of a rubber pipe into storage tanks, whence it is pumped by a centrifugal pump to a tank 5 feet above level of the leaching vats.

Polysulphide of calcium solution. CaS_5.

	Diameter.	Height.
A	8′	6½′
B	6′	6′
C	10′	3′

The vat *A* is filled up to 1 foot with water and boiled with steam. Then quicklime is added and the boiling is continued for a while. Finally, sulphur is added and the boiling continued for five or six hours. The stirring is done mechanically. The proportions are as follows:

Sulphur	70
Lime	100

The solution obtained after settlement is decanted into a storage tank. The residue is treated again with water and steam and then a smaller quantity of lime and sulphur are added in the proportion of $CaO = 79$. $S = 56$.

This second residue is discharged on the sand filter of vat *B*. When dry it is put aside and exposed to the atmospheric action. A long exposure of this residue gave us 6·2 per cent. of calcium hyposulphite. Each operation gave us 6,213 liters of calcium polysulphide at a cost of 69 cents.

Let me mention that sulphur in Aduana costs 7·4 cents per pound.

[*To be concluded.*]

CHEMICAL SECTION.

Stated Meeting, February 15, 1898.

THE CHEMICAL COMPOSITION AND TECHNICAL ANALYSIS OF WATER GAS.

BY EDWARD H. EARNSHAW,
Chemist to the United Gas Improvement Company, Philadelphia, Member of the Institute.

(*Concluded from p. 176.*)

SUPPLEMENTARY NOTE.

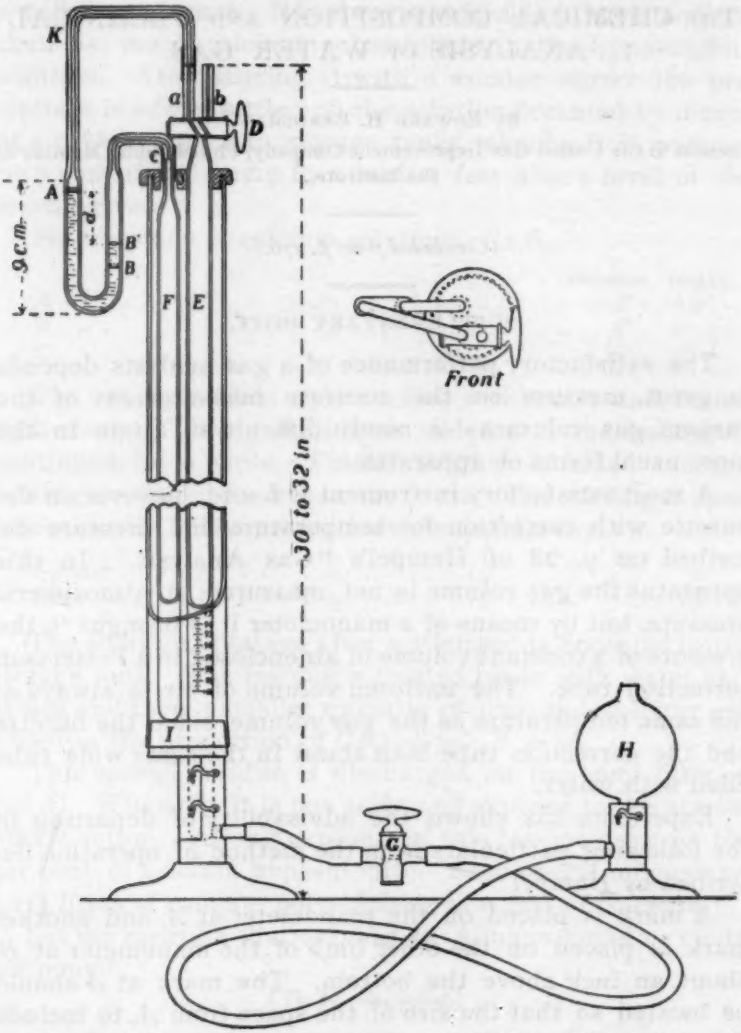
The satisfactory performance of a gas analysis depends in great measure on the accurate measurement of the various gas volumes—a result difficult to attain in the more usual forms of apparatus.

A most satisfactory instrument is found, however, in the burette with correction for temperature and pressure described on p. 28 of Hempel's "Gas Analysis." In this apparatus the gas volume is not measured at atmospheric pressure, but by means of a manometer it is brought to the pressure of a constant volume of air enclosed in a Pettersson correction tube. The enclosed volume of air is always at the same temperature as the gas volume, since the burette and the correction tube both stand in the same wide tube filled with water.

Experience has shown the advisability of departing in the following particulars from the method of operation described by Hempel:

A mark is placed on the manometer at *A*, and another mark is placed on the other limb of the manometer at *B*, about an inch above the bottom. The mark at *A* should be located so that the size of the space from *A*, to include the stopcock *D*, shall be exactly 1 cubic centimeter. This may readily be done thus: Withdraw the manometer tube from the connection at *C*, then, by raising the level bulb *H*,

fill the measuring tube and manometer completely full of water. Now draw some air into the burette and note the volume at atmospheric pressure, after allowing sufficient time for the water to run down. Then turn the stopcock *D*



so that the burette communicates with the manometer, and, by raising the level bulb, pass a little air over into the manometer, and at the same time force a little of the water

out of the open end of the tube at *C*. By a little manipulation the volume of the air in the burette may thus be diminished by exactly 1 cubic centimeter, while at the same time the liquid in the manometer stands at the same height in both sides.

In the ordinary use of the burette it is very inconvenient to measure the gas volume with the liquid in the manometer at the same level in both sides, because there is great liability that some of the water will accidentally be forced over into the correction tube, and also because a free space is needed to enable the water in the manometer to be moved up and down, and thus clear the connecting tube of the annoying drops of water which persistently remain in it. It is therefore better to make the measurement as follows: Draw the water in the manometer over into the burette until the liquid in one side stands exactly at the mark *B*, and the other side is completely filled to the stopcock *D*. When now the gas volume in the burette is to be measured, turn the stopcock *D* so that the burette communicates with the manometer, and, by raising or lowering the level bulb *H*, bring the water in one side of the manometer exactly to the mark *A*; the liquid in the other side of the manometer will then stand at *B'*. Close the stopcock *G*, and note the size of the gas volume, which will be the reading of the scale plus 1 cubic centimeter.

By this method the pressure in the burette, instead of being equal to the pressure in the correction tube *F*, will differ from it by a constant amount equal to the difference *d* between the levels of the liquid in the two arms of the manometer.

It will usually happen in drawing the gas in the manometer back into the burette that the liquid in the manometer will be drawn slightly below the mark *B*. This is of no consequence, as, when the gas has been passed from the burette to the absorption pipette, the stopcock *D* may be turned, and a little water passed from the burette into the manometer. By this method of operation it is assured that the measurements of the gas during an analysis will be made under absolutely uniform conditions.

Before beginning an analysis, it is advisable to bring the water in the manometer to the mark *A*, close the stopcock *D*, and draw the manometer tube out of the connection at *C*. This will establish atmospheric pressure in the burette and correction tube.

Some points in the construction of the burette are worthy of note. The measuring tube *F* should have an internal diameter of about 15 millimeters; the instrument will then have a total height of 30 to 32 inches. The correction tube may be about the same size, or slightly smaller, and must be just long enough to rest on the rubber stopper *I*, at the bottom and project about ½ inch above the wooden cap *J*. This wooden cap serves to hold the tubes in their proper position in the water jacket, and also prevents the manometer from sagging down. The water jacket tube must be cut of such length that the rubber stopper *I* rests firmly on the burette base, while the top of the tube ends about 1 inch below the stopcock *D*. In *Fig. 1* the correction tube and burette are, for convenience' sake, shown side by side. As a matter of fact, they are arranged as shown in *Fig. 2*. The holes are carefully bored in wooden cap and rubber stopper so as to bring the measuring tube parallel to and near the front of the water jacket. The correction tube is placed behind and to one side of the measuring tube, and the connecting tube to manometer is bent at an angle, as shown.

The U-shaped part of the manometer is about 9 centimeters long and 8 millimeters internal diameter. The connecting tube *K* is 6 millimeters outside diameter and 2 millimeters bore. The capillary tubes *a* and *b* are 1½ inches long and 1 millimeter bore.

The stopcock *G* should be large, and it will be found necessary to secure it in a small wooden block fastened to the table in a convenient position. The iron foot of the burette should also be screwed to the table, as the apparatus is quite top-heavy. It is convenient to use two burettes for the analysis. One is graduated from the stopcock *D* to 100 cubic centimeters in tenths of 1 cubic centimeter, and is used for the direct absorptions; the other is graduated from 60 cubic centimeters to 100 cubic centimeters in twentieths,

the upper part of the measuring tube being enlarged into a cylindrical bulb and not graduated. This látter is used exclusively for the explosions and combustions, where great accuracy is essential.

Stated Meeting, September 20, 1898.

IN MEMORIAM.

HENRY TRIMBLE.

The Franklin Institute has lost another of its members and active supporters, and chemical science one of its trained workers and devoted followers in the death of Prof. Henry Trimble, which took place at St. Davids, near this city, on the 24th of August, 1898.

Those of our number, who had the pleasure of an intimate acquaintance with him, and knew that under a quiet and somewhat retiring manner lay a warm heart and devoted friendships, feel in addition a sense of personal loss that cannot easily be weighed or expressed by the use of ordinary conventional phrases.

Henry Trimble was born near Chester, Pa., on May 22, 1853, the son of Stephen M. Trimble, a member of the Society of Friends. He was brought up on a farm, going to school in winter and working during the summer. His earlier education was obtained at the well-known Westtown School in Chester County, and at the age of nineteen he was apprenticed to learn the drug and apothecary business.

Two years later, in 1874, he entered the Philadelphia College of Pharmacy, the institution in which most of his subsequent active career was to be cast, and was graduated therefrom in 1876. Desiring to supplement his course here by a fuller training, he then entered the University of Pennsylvania as a special student in chemistry, to which branch of scientific study he felt already strongly drawn. He continued here during two years, working in the analytical laboratory under the late Dr. F. A. Genth, and for the last year of his time there acting as lecture assistant to Professor Sadtler,

who then held the chair of General and Organic Chemistry in that institution.

When in the fall of 1878, Professor Sadtler was called to the College of Pharmacy to take the lectures of the late Dr. Robert Bridges (then the Professor of Chemistry there), he took Henry Trimble as his lecture assistant there also. In this same year, 1878, he established himself in the retail drug business, with his friend and classmate, C. W. Warrington, the two taking the business of their preceptor, S. Mason McCollin, M.D., at Fifth and Callowhill Streets, in this city.

Meanwhile the chemical laboratory of the College of Pharmacy having also come under the care of Professor Sadtler, by reason of the resignation of Dr. Fred. B. Power, Henry Trimble was given the active supervision of this, and in 1883, having retired from active connection with the drug business, he was given the full rank and title of Professor of Analytical Chemistry in the institution.

From this time on, all his energies and efforts were given to this work, and the literature of pharmacy and chemistry will bear witness that, all too short as was his term of scientific activity, he left his mark upon their pages.

As director of the laboratory he had to plan and supervise the work of advanced students, and each year many original investigations in analytical chemistry and proximate plant analysis were carried out under his guidance.

The list of published articles which appeared in the *American Journal of Pharmacy*, under his name during the years 1875–1898 was fifty-four in number.

Already, in 1890, he had begun to make a special study of the class of vegetable principles known as tannins, being incited thereto by some investigations which he had made into the methods of dyewood extract manufacture. So in 1892 he published, in a small octavo, the first volume of a work with the following title: "The Tannins; a monograph on the history, preparation, properties, methods of estimation and uses of the vegetable astringents." In 1894 he followed this by a second volume, and, at the time of his

HENRY TRIMBLE.
1853–1898.

death had a large amount of unpublished notes which were meant to be used in a continuation of this unique publication. It is strictly correct to say unique, because the work at once took rank in this country and abroad as the authoritative work on the subject, and Professor Trimble had for years carried on an extensive correspondence with botanists and chemists in all parts of the world upon what was known as his specialty.

In this connection it should not be overlooked that Professor Trimble was an accomplished botanist, having taken special advanced instruction in this subject while a student at the University, and afterwards from Professors Rothrock and W. P. Wilson.

This familiar acquaintance with the two domains of chemistry and botany made it an easy matter, therefore, for him to co-operate with his colleague, the late Prof. E. S. Bastin, in a series of joint articles on "Some North American Coniferæ," which appeared in the *American Journal of Pharmacy*, and were reprinted in separate form in a pamphlet of some 124 pages.

He also became a contributor to *Garden and Forest*, published under the editorship of Professor Sargent, of Harvard University, and during the years 1894–98 furnished seven articles for this periodical. An article on the Coniferæ was also contributed by him to Sargent's monumental work, "Silva of North America," appearing in Volume XI.

In 1885 he published a small "Handbook of Analytical Chemistry," for the use of his laboratory students. It ran through several editions and was then merged into the "Text Book of Pharmaceutical and Medical Chemistry," first published by Professor Trimble and Professor Sadtler jointly in 1895, and which has just appeared in a second revised edition.

As a member of the Franklin Institute, Professor Trimble was called upon several times to lecture in the regular winter lecture course, and only a year or so ago gave us here a most instructive lecture upon the recent researches into the composition of "Natural Resins." These lectures of his will be found printed in full in our *Journal*.

Professor Trimble has repeatedly received public honors which came as a recognition of his attainments. He had the honorary degree of A.M. conferred upon him by Haverford College in 1896.

In 1895, he was selected as one of the Judges of Award for the Atlanta Exposition in the Forestry Section.

In 1897, he was elected a member of the American Philosophical Society, and because of his knowledge of the branch of sylviculture was made a member of the Standing Committee on the Michaux Legacy.

In 1894, he was elected editor of the *American Journal of Pharmacy*, to succeed the late John M. Maisch, and at once threw himself with additional energy into this new sphere of work.

This editorial labor, with the necessary correspondence and work of proof-reading for each monthly issue, which he would not delegate because of his feeling of personal responsibility, proved too much for his strength, already tasked quite sufficiently.

In the spring of 1897, he broke down partially and was forced to give up some of his work. But improving somewhat, he took up his joint college and editorial work again, and continued until in May, 1898, he was forced to place the editorship of the *Journal* in other hands and seek entire rest.

But the seeds of fatal disease were already sown, and in August came the end of his life's activity.

He has left us a name and a memory. A name for workers in his chosen science, and especially for young men to emulate, as he showed in his career what a plain farmer's son could make of himself by effort. A memory for those who were privileged to know him, of a true-hearted and faithful friend, who was always the same, and whose word could always be relied upon implicitly.

A list of published papers and other works of Professor Trimble will be found appended to this memoir.

SAML. P. SADTLER,
CHAS. BULLOCK,
T. CHALKLEY PALMER.

PUBLISHED PAPERS OF HENRY TRIMBLE.

I. *American Journal of Pharmacy.*

1875. Assay of quinine pills.
1876. Benzoic acid as an antiseptic.
1877. Concentrated nitric acid.
Estimation of quinine.
1878. Analysis of dialysed iron.
1881. Preparation of formic ether.
1883. Milk analysis.
1884. Menthol.
1885. Glycerin vapors.
Oils of peppermint and spearmint.
Polygonum hydropiper (jointly with H. J. Schuhard).
Burdock Fruit (jointly with F. D. McFarland).
1886. Analysis of Yerba del Indio (jointly with S. S. Jones).
Analysis of Phlox carolina.
1887. Amyl acetate.
Laboratory notes.
1888. Sheperdia argentea.
Bitter principle of burdock fruit.
Catechu and gambier.
Precipitated ferrous sulphate.
Solid hydrocarbons in plants (jointly with Helen C. De S. Abbott).
1889. Canaigre.
Some Indian plant foods.
Fabriana imbricata (jointly with H. J. M. Schroeter).
Oil of camphor (jointly with H. J. M. Schroeter).
Oils of wintergreen and birch (jointly with H. J. M. Schroeter).
Old sample of camphor oil (jointly with H. J. M. Schroeter).
1890. Eupatorium purpureum.
California soap plant.
Peucedanum Canbyi.
Some American galls.
Oils of wintergreen and birch (jointly with H. J. M. Schroeter).
1891. Carum Gairdneri.
Geranium maculatum (jointly with J. C. Peacock).
1892. Examination of some official preparations.
Purshia tridentata.
1893. Proximate principle from Phytolacca decandra.
Preparation of oak tannins, acetone a solvent (jointly with J. C. Peacock).
Canaigre tannin (jointly with J. C. Peacock).
1894. Four oak barks from India.
Cultivation of ginseng.
1895. Oils of wintergreen and birch.
Report on tannin from dragon's blood.
1896. Recent literature on soja bean.
Tannin of some acorns.

1897. Occurrence of strontia in plants.
Pomegranate rind.
Tannin of Castanopsia.
Tannin of Ceriops candolleana.
The soy bean.
The willow bark.
North American coniferæ (jointly with Prof. E. S. Bastin).
1898. An exudation from Larix occidentalis.

II. *In Garden and Forest.*

1894. Pin oak (Quercus palustris).
1895. On the tanning properties of the bark of three North American trees.
1896. Salt and sugar in Washingtonia filamentosa.
Tannin value of North American trees.
Tannins of the palmetto.
1897. Source of abietene.

III. *In Franklin Institute Journal.*

1887. Tannin, its present and future sources.
1892. Chestnut bark tannin.
1897. Recent advances in the study of the resins.

PROFESSOR TRIMBLE'S BOOKS.

I. *Hand-book of Analytical Chemistry, 8vo. P. Blakiston, Son & Co.*

1st edition, 1885.
2d edition, 1886.
3d edition, 1889.
4th edition, 1892.

II. *The Tannins—a Monograph. J. B. Lippincott Co.*

Vol. I, 1892.
Vol. II, 1894.

III. *Text-book of Pharmaceutical and Medical Chemistry (jointly with S. P. Sadtler).*

1st edition, 1895. J. B. Lippincott Co.
2d edition in two volumes, 1898. J. B. Lippincott Co.

NOTES AND COMMENTS.

THE LATEST SCHEME FOR THE PASSAGE OF THE ENGLISH CHANNEL.

Since the collapse of the long-mooted project for a tunnel under the English Channel, connecting England and France, but little has been said concerning the subject of facilitating the channel passage. Interest in the subject has at length been revived by the publication of a scheme which is referred to by *Industries and Iron* as having lately been brought to the attention of the authorities in London and Paris. The journal in question gives the following outline of the present project:

The idea is to secure a passage for trains without involving the cost of a bridge or the danger of a tunnel, and may be described as an exemplification of the electric railroad on submarine rails, carried out on a small scale from Brighton to Rottingdean, England.

It is proposed to lay rails on a track about fifty feet below low-water level, and the train would be conveyed from Dover to Calais, or *vice versa*, on a tower-like structure running on these rails in the bed of the straits. The train platform would be about 500 feet long and 50 feet wide, carried on five steel columns on each side, and these would be braced to and supported on a submerged platform on the series of rails, which would be 100 feet wide. Steam engines and dynamos on the train platform would provide the power for rotating the train wheels on the lower platform. The cost of the undertaking is estimated at fourteen million pounds sterling (about $70,000,000), and five years is the limit of time in which it could be completed. W.

ALUMINUM FOR ELECTRIC CONDUCTORS.

Mr. Alfred E. Hunt, who is prominently identified with the development of the aluminum industry, has lately presented, in the columns of the *Electrical World*, a strong argument in favor of the substitution of aluminum in place of copper for electric conductors, for telegraph, telephone and railway services.

Mr. Hunt points out that while the electric conductivity of aluminum is 63 per cent. of that of copper, the weight of the latter metal is 3·33 times that of an equal volume of aluminum. From this it appears that even by increasing the cross-section of an aluminum conductor sufficiently to give it equal conducting with copper, the weight of the larger aluminum conductor would still be only 48 per cent. of that of the copper conductor.

As to the matter of cost, Mr. Hunt says:

"To obtain, therefore, a conductor of aluminum at the same cost of metal per mile, the cost per pound of the aluminum may be 2·1 times greater than that of copper. Assuming the cost of the copper at 14 cents per pound, it is evident that aluminum at 29 cents per pound is slightly cheaper than copper."

Furthermore, the important matter of tensile strength in this comparison

determines itself in favor of aluminum. Aluminum wire can be supplied at about the same tensile strength per unit of area as that of annealed copper—32,000 pounds per square inch; but as the aluminum conductor will have a larger area to make up for its deficient conductivity, it will be the stronger.

With reference to the use of alloys of aluminum for this purpose, Mr. Hunt points out that while a number of such alloys can be made which are much stronger than the pure metal, they appear as a class to reduce the electric conductivity. One of these alloys which he refers to, however, appears to be well adapted for the production of electric conductors. It has a tensile strength of 65,000 pounds per square inch, and an electric conductivity of 50.

The one difficulty that is encountered in the manipulation of aluminum is that of soldering or brazing it, and this would be encountered here also. It is suggested that mechanical joints might be tried with more prospects of success. On the other hand, the difficulty would probably be entirely obviated by the adoption of the method of electric welding by which no foreign metals would be brought into contact with the aluminum.

The experiment of using aluminum for this purpose has been made with apparently satisfactory results in this country and in Germany. It resists corrosion very well. W.

A SLIDING OVERHEAD TROLLEY.

The use of the under-running roller trolley has become so universal for electric cars, that its superiority over other forms has been taken for granted. It now appears that the Germans have made some very satisfactory trials of a sliding contact trolley, which show that the alleged superiority of the roller is more apparent than real.

The following facts in relation to this point are given in *Engineering Magazine*, and relate to the use of a double or forked trolley arm which carries a light, slightly-bowed horizontal bar, which is pressed upward against the conducting wire in the manner of a trolley wheel, the contact being entirely a sliding one. The contact bar is formed of an aluminum channel bar, with a central bar of white metal, the spaces between being filled with a lubricating grease. This is the plan in use on the trolley system of Dresden.

The bar thus constructed lasts from six to eight weeks, corresponding to 8,000 car kilometers (6,400 car miles), and the general results are satisfactory. Also, contrary to what might be supposed, the wear on the line wire is less than with the roller trolley; for, with the roller, the side wear on the wire is very great, especially upon curves, which, with the sliding bar, after a slight flat bearing has been worn on the conductor, further wear seems to be trifling. On the Dresden lines the conductors are of copper. At Basle the line wire is of aluminum, and therefore of greater diameter. In this case the contact area is increased and the wear is diminished. The sliding trolley bar in this case lasts two or three times longer.

It is reported that, in addition to the two cities above named, the sliding trolley bar has been given practical service in Berlin, Mulhausen, Hanover, Barmen and other German cities, and that it has been found preferable to the roller trolley for the reasons above named. W.

CRYPTON: A NEW ELEMENT IN AIR.

London advices of recent date refer to the probable discovery by Professor Ramsey (who, jointly with Lord Rayleigh, discovered argon) and Mr. Morris Travers, of another hitherto unknown gas existing in the atmosphere. A brief account of the work of these investigators was lately communicated to the French Academy of Sciences through M. Berthelot, the principal facts of which are as follows: Messrs. Ramsey and Travers received from Dr. Hampson 750 cubic centimeters of liquid air, which was partially evaporated. The residual liquid furnished a gas in which the supposed new element was detected. The method of procedure consisted in absorbing and removing the oxygen and nitrogen by well-known methods, after which there remained 26 cubic centimeters of gas, which, when examined with the aid of the spectroscope, exhibited spectrum lines unlike those of any hitherto known gas.

The facts as reported seem to indicate, according to the authors, that the atmosphere contains a hitherto unknown gas heavier than argon, with a characteristic spectrum, and less volatile than either nitrogen, oxygen or argon. Professor Ramsey is disposed to class it with the recently-discovered element helium. Larger quantities of the gas are being prepared for the more thorough study of its properties.

Professor Ramsey names the new substance "crypton." W.

REMEDY FOR DIFFICULTIES IN BURNING ACETYLENE GAS.

Prof. Vivian B. Lewes, an eminent English chemist, who has done much valuable work in extending our knowledge of the properties and applications of acetylene gas, has lately contributed an interesting paper on this general subject to the (English) Society of Chemical Industry. In this communication he deals at some length with the difficulty which exists in finding a suitable burner in which to consume the gas, and throws much light upon the cause of the difficulty. All who have had experience with acetylene are familiar with the fact that there is a persistent disposition to the deposition of soot in the burner tip, which, in the course of a short time causes the clogging of the tip, followed by the distortion of the flame and pronounced smoking. Numerous efforts have been made to do away with this objectionable feature, but thus far with only partial success. Among the remedies that have been proved most satisfactory is the Naphey burner and its various imitations, but these have proved to be by no means infallible, and the difficulty appears to be as far from solution as ever.

Professor Lewes has studied the character of this soot deposit and offers some explanations of its nature and cause, which point to the proper remedial measures.

It has been generally supposed that the soot deposit noticed in the burner slit or tip consuming acetylene was due to the dissociation of the gas from overheating at the nipple, the decomposition resulting in the separation of carbon. Professor Lewes believes this is not the true explanation of the origin of this deposit.

On breaking open the steatite tip of such a burner, he found a carbona-

ceous deposit extending for a considerable distance into the body of the steatite, and this he holds to be evidence of the fact that the deposit has been caused by the deposition of a liquid hydrocarbon, which has soaked into the steatite and been carbonized there. He calls attention to the fact that the same trouble is experienced to some extent with carburetted water gas, when, owing to insufficient temperature in the cracking and superheating chambers, the carburetted gas contains vapors instead of permanent gaseous products. His observations lead him to the belief that the trouble in the case of acetylene arises from a similar cause, namely, the presence in the gas of condensible hydrocarbons, the origin of which he explains as follows:

"When acetylene has been made in a generator at an undue temperature, it carries with it benzene vapor, which, as it commences to condense, assumes a vesicular form (like smoke or tar vapor), and on coming to the extremely minute holes which form the apertures of the burner, the mechanical scrubbing which it encounters causes the breaking up of the vesicles and the deposition of the benzene and other hydrocarbons held in suspension in the gas, which soak into the steatite and carbonize. The presence of finely divided carbon has a great effect in determining the decomposition of acetylene itself, so that a rapid growth of carbon takes place at the burner, and no ordinary cleaning from the exterior will ever make the nipple fit for constant use again."

The remedy for the trouble, Professor Lewes believes, must be sought for in the improvement of the automatic acetylene generators in service, with the object in view of avoiding undue heating in the process of generating the gas. If proper attention is paid to this point, not only will the sooting of the burner be largely avoided, but there will also be obtained an appreciable increase in the yield of the gas from the carbide. His conclusions are expressed in the following terms: "It will be found with experience that the prevention of smoking in a burner will be effected quite as much by attention to the temperature in the generator as to the burner itself, and where a generator is in use which gives overheating, a well-arranged scrubbing apparatus that would get rid of the benzene in the gas, would be found a distinct advantage in stopping burner troubles."

The practical hints herein given by Professor Lewes should prove of the utmost value to those who are engaged in the manufacture of acetylene machines, and the users of the gas. W.

THE UNFITNESS OF CAST-IRON COLUMNS IN BUILDING CONSTRUCTION.

Prof. William H. Burr has given, in the School of Mines Quarterly, a timely warning against the continued use of columns of cast-iron in building construction which it would be well for architects to bear seriously in mind. Professor Burr shows that the rules followed by engineers in respect of the loading per square inch of cast-iron columns in buildings are based on experiments made sixty years ago, on small cross sections (solid and hollow), not over four inches in diameter, and with lengths not exceeding ten feet.

Commenting on this fact Professor Burr very properly makes the criticism that columns of such diameters—particularly if cast for experimental purposes—will obviously be far freer from the internal defects so common to full-sized cast-iron members than the columns used in structures, and he adds that it has long been accepted as one of the cardinal principles in civil engineering that the untimate resistances of full-sized members of all descriptions can only be determined with sufficient accuracy for the best practice by testing such full-sized members to failure.

The fact that civil engineers have long since excluded cast-iron columns from bridge structures affords evidence of the unfitness of cast-iron for such service, and renders it the more important in view of the continued use of this material in buildings, that engineers should have at command the results of destructive tests of full-sized members of cast-iron from which the working loads that such columns may safely bear may be determined.

Such needed tests, Professor Burr points out, were begun in 1888-1889, at the United States Arsenal, at Watertown, Mass., the large Emery testing machine being used for the purpose. These were followed in 1896–1897 by a series of tests of similar character made at Phœnixville, Pa., under the auspices of the Department of Buildings of New York City.

The tabulated results of these tests show considerable variations in the ultimate resistances even for the same ratio of length over diameter. Thus, in Nos. 1 to 6, in which the ratio of length was 12·7, the ultimate resistances vary from 24,000 pounds per square inch to over 40,000 pounds per square inch, with no fraction at the latter value. Again, No. 25 (ratio less than 20), exhibited an ultimate resistance of nearly 47,000 pounds per square inch, which is excessively high.

These erratic results, Professor Burr adds, are not to be regarded as surprising when the ordinary character of cast-iron is considered. Failures of columns, he continues, are frequently found recorded with remarks as the following: "Foundry dirt or honey-comb," "bad spots," "cinder pockets and blow holes near middle of column," "flaws and foundry dirt at point of break." Which means that it is a common experience to find that defects, such as flaws, or blow holes, or thin metal determined the place of failure.

Professor Burr then submits to a critical examination the present formula in use for the proportioning of cast-iron columns, and concludes that for hollow round columns of this material it is grossly wrong, both as to the law of variation of ratio of length over diameter and as to the value of ultimate resistances. He illustrates his argument with the aid of a graphical diagram which exhibits that present practice is based upon an utterly erroneous and dangerous formula.

Of much interest is the concluding portion of this paper, in which Professor Burr compares the ultimate resistances per square inch of mild-steel columns—as determined by actual tests with the ultimate resistances of cast-iron columns. From this comparison it appears that the steel column is from 40 to 50 per cent. stronger than the cast-iron columns—the same ratio of length over diameter being taken in each comparison. He concludes not taking into consideration the erratic and unreliable character of cast-iron, these tests

show that the safe working resistance per square inch for mild-steel columns may reasonably be taken as twice as great as for cast-iron.

He concludes his strong argument in favor of the exclusion of the cast-iron columns from building construction, and the substitution therefor of steel columns, with the following recapitulation:

"The series of tests of cast-iron columns (herein referred to) largely destroys confidence in the cast-iron column designs of the past. The results of the tests constitute a revelation of a not very assuring character in reference to cast-iron columns now standing, and which may be loaded approximately up to specification amounts. They further show that, if cast-iron columns are designed with anything like a reasonable and real margin of safety, the amount of metal required dissipates any supposed economy over columns of mild steel. As a matter of fact, these results conclusively affirm what civil engineers have long known, that the use of cast-iron columns cannot be justified on any reasonable ground whatever." W.

Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, September 21, 1898.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, September 21, 1898.

MR. JOHN BIRKINBINE, President, in the chair.

Present, 92 members and visitors.

Additions to membership since last report, 4.

Mr. Robert D. Kinney was elected a member of the Committee on Science and the Arts, for the unexpired term of Mr. P. A. Winand, resigned.

Mr. Paul J. Schlicht, of New York, presented a paper on "A New Process of Combustion." Mr. Schlicht's process is an automatic down-draught system, adapted to furnaces of all kinds; not only to furnaces of steam boilers, but also to house heaters. The communication was discussed by Messrs. Outerbridge, Scott, LeVan and the author. The paper is reserved for publication, and the subject was referred for investigation and report to the Committee on Science and the Arts.

Mr. R. J. Fisher, of New York, exhibited and described the Fisher Book-Typewriter. The machine is designed for printing directly in record books, and may be readily converted into an ordinary writing machine for correspondence. (Referred to the Committee on Science and the Arts.)

Mr. Ernest M. White, of Philadelphia, exhibited and described certain improvements in chimneys and globes for incandescent gas lights. They are designed, respectively, to permit the use of torn and otherwise imperfect

mantles of the Welsbach type, which would otherwise have to be discarded, and to protect the light from extinguishment by wind or drafts.

The Secretary exhibited and described the Mason Safety-Tread for stairways, sidewalk lights, etc. An abstract of the monthly report appears in the *Journal*.

Adjourned.

WM. H. WAHL, *Secretary*.

COMMITTEE ON SCIENCE AND THE ARTS.

[*Abstract of proceedings of the stated meeting held Wednesday, September 7, 1898.*]

MR. SAMUEL SARTAIN, in the chair.

Reports on the following subjects were considered:

(No. 2003.) *Automatic Air-Brake Mechanism.*—G. F. Jeffries, Reading, Pa.

(No. 2009.) *Chimney for Incandescent Gas Lights.*—Ernest M. White, Philadelphia. [Referred back to Sub-committee for revision.]

The following cases were terminated.

(No. 1977.) *Trolley-Car Fender.*—Henry Lotzgesell, Philadelphia.

ABSTRACT.—The device is made of three metal frames, of about the width of the car tracks, with rope netting stretched across them, and being hinged together and so mounted and secured to the front of the car that normally two of the frames form an inclined plane reaching from about the height of the car floor to a point very near the ground. The third frame stands upright at the back of the other two and near the car dasher.

The whole structure may be adjusted at any desired angle by chains and side bars, and the front edge of the lower frame is furnished with a buffer of soft material for the protection of a person struck by it.

The hinged sections are so connected that they will fold up partially when a heavy body falls upon them, thus furnishing a crib within which the person is held.

Provision is also made by which the whole structure can be folded up close to the car dasher, and for transferring the fender from one end of the car to the other. The device can be cheaply built from materials purchasable on the market.

The report speaks of the device as "a good one," but finds that almost all of the details thereof have been anticipated by other patentees. A list of these anticipating patents is appended to the report.

The invention is covered by letters-patent of United States, No. 570,099, October 27, 1896, to Henry Lobzgesell. [*Sub-Committee.*—H. R. Heyl, Chairman; T. Carpenter Smith.]

(No. 1963.) *Ordinance for the Regulation of Smoke Nuisance.*

The Sub-Committee to which the draft of ordinance previously submitted was referred for further consideration, presented an amended draft. This was discussed, amended in unessential features, and adopted. Ordered to be transmitted to the Board of Managers. [*Sub-Committee.*—A. E. Outerbridge, Jr., Chairman; John Birkinbine, Chas. A. Hexamer, Dr. Coleman Sellers.]

(No. 1999.) *Protest* of Thos. Armat, Washington, D. C., against the award to C. Francis Jenkins for his phantoscope.

The Sub-Committee presented a report reviewing the statements and claims of Mr. Armat in detail. The Committee concludes that the protestant had failed to establish his objections. Report adopted and protest dismissed. [*Sub-Committee.*—H. R. Heyl, Chairman; John Carbutt.]

(No. 2010.) *Protest* of John S. Cook, Atlanta, Ga., against report on his invention of an improved journal-box.

The Sub-Committee, after examination of Mr. Cook's objections, reported in favor of sustaining the report as originally made and adopted. [*Sub-Committee.*—J. Logan Fitts, Chairman; H. F. Colvin.] W.

SECTIONS.

MINING AND METALLURGICAL SECTION.—*Stated Meeting* held Wednesday, September 14th. Mr. A. E. Outerbridge, Jr., President, in the chair.

The meeting was devoted to an informal discussion of the work of the Section during the present season. The preliminary program for the year was presented and read.

CHEMICAL SECTION.—*Stated Meeting* held Tuesday, September 20th, Dr. Lee K. Frankel, President, in the chair.

Dr. Frankel made some remarks appropriate to the inauguration of the season's work, and presented and commented on the preliminary program of papers prepared by the Committee on Papers.

Mr. Hudson Maxim, of New York, presented a paper, entitled "High Explosives and Smokeless Powders, and their applications in Warfare." The speaker gave a historical introduction to his theme, and proceeded to advocate the use of projectiles containing heavy charges of high explosives in great guns, which, he claimed, could be done with safety, and with destructive effects enormously greater than with the small explosive charges of black powder at present issued with heavy projectiles. [Referred for publication.] W.